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WEEKLY 16 April 2022

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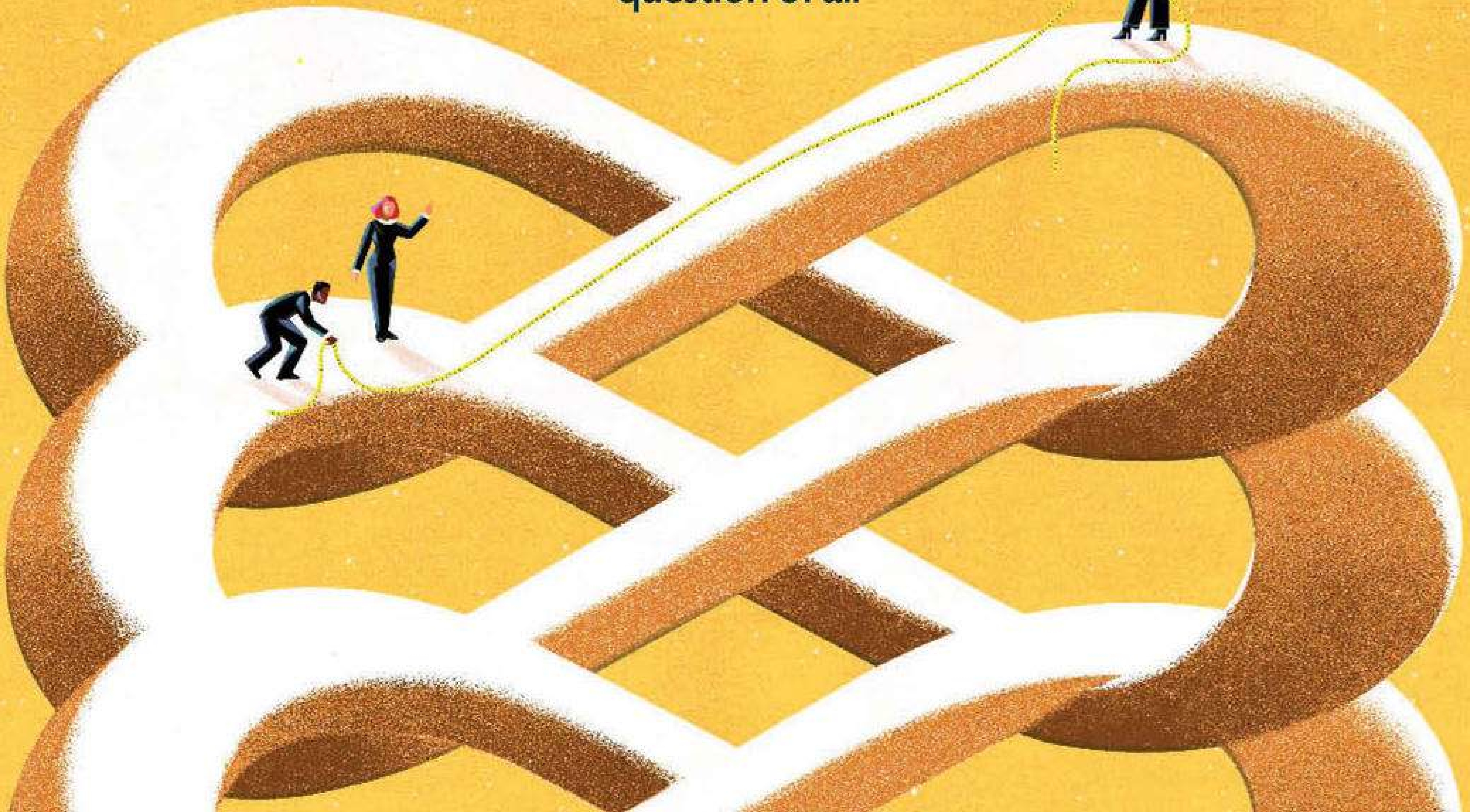

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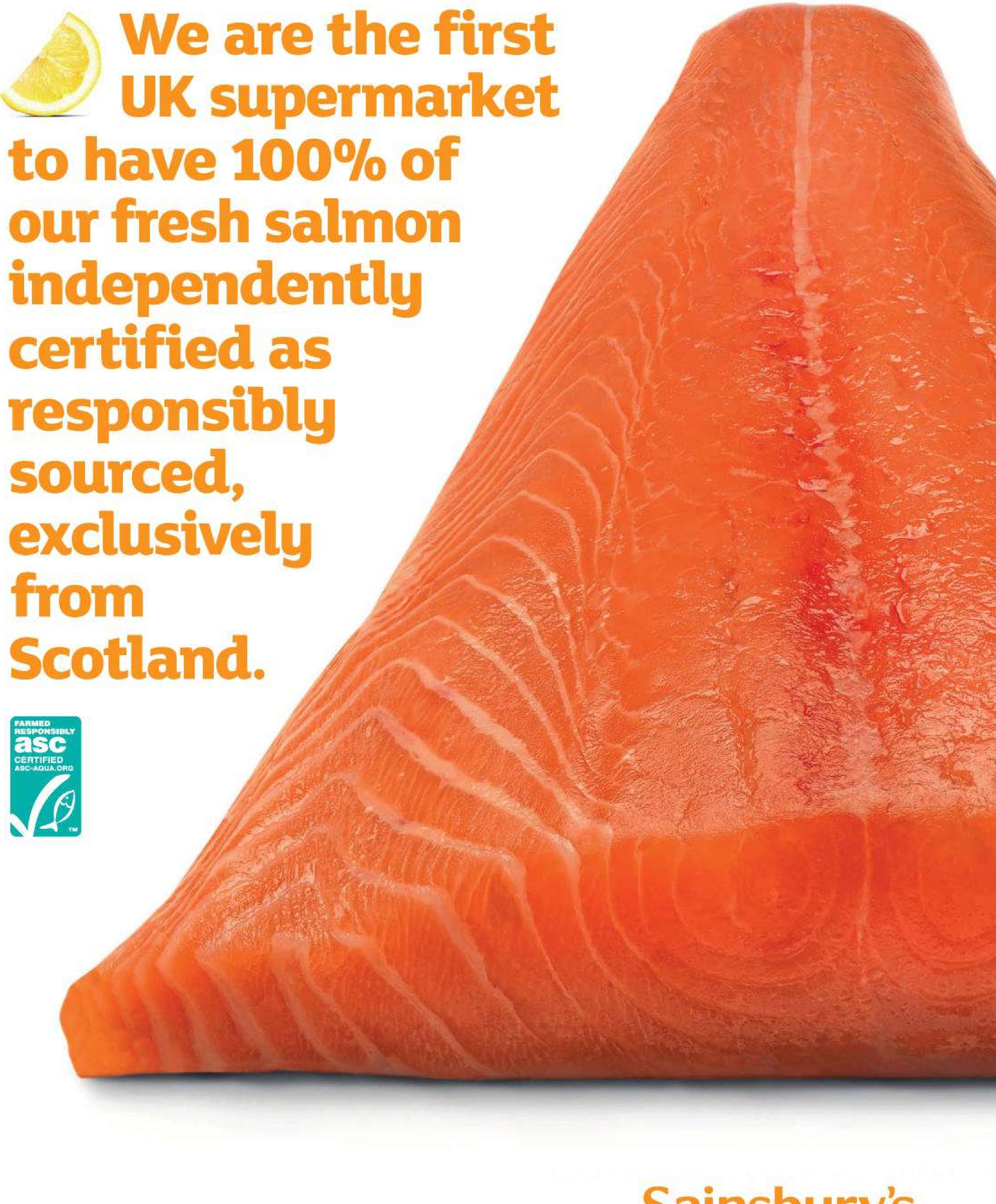
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A new answer to the largest question of all

New Scientist
HOW BIG IS INFINITY?
A new answer to the largest question of all

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Why we love

Love is an awe-inspiring and complex phenomenon. In this talk, evolutionary anthropologist Anna Machin will take you through a rollercoaster ride of the why, how, who and what of love. She will explain how love evolved as a form of biological bribery, why it is the greatest factor in our health and longevity and the reasons it sits at the centre of what it is to be human. Online at 6pm BST on 5 May and later on demand.

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Discovery tour

Ancient caves, human origins: Northern Spain

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Podcasts

Weekly

The team tackle the latest warning that time is running out to keep global warming to below 1.5°C, including what role litigation could play. They also discuss claims that a new measurement of the W boson could rewrite particle physics, and the extraordinary genitalia of female wētā crickets.

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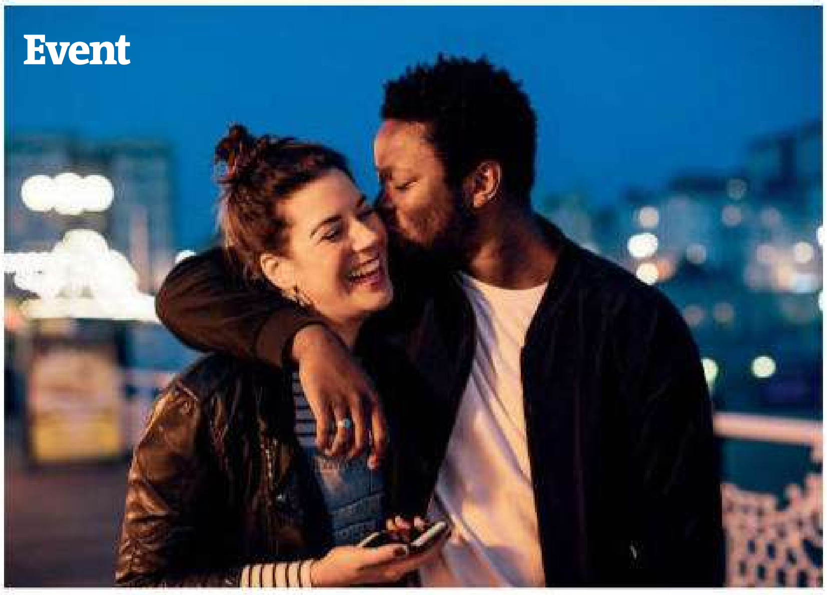

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Intimate detail Discover what science has to say about love

HEMIS/ALAMY

Pachyderm protection See how camera traps are saving elephants

Video

Caught on camera

AI-powered camera traps have given wildlife rangers in Gabon a new tool to fight poaching and biodiversity loss. The country is a biodiversity hotspot, hosting one of the largest populations of the endangered African forest elephant. Now, researchers are using the camera traps to help monitor and protect this and other species.

youtube.com/newscientist

Newsletter

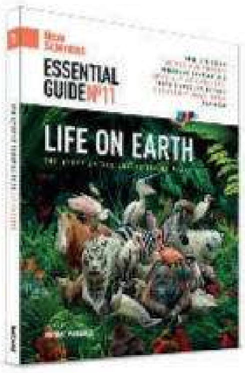
Lost in Space-Time

Executive editor Richard Webb explains the transformative power of gravitational waves and their potential for giving us new insights into the lives and deaths of stars, as well as the formation and evolution of galaxies. Plus, he grapples with a mind-bending question: Are quantum states real?

newscientist.com/ lost-in-space-time

Newsletter

> **"We might have already seen the gravitational wave background"**



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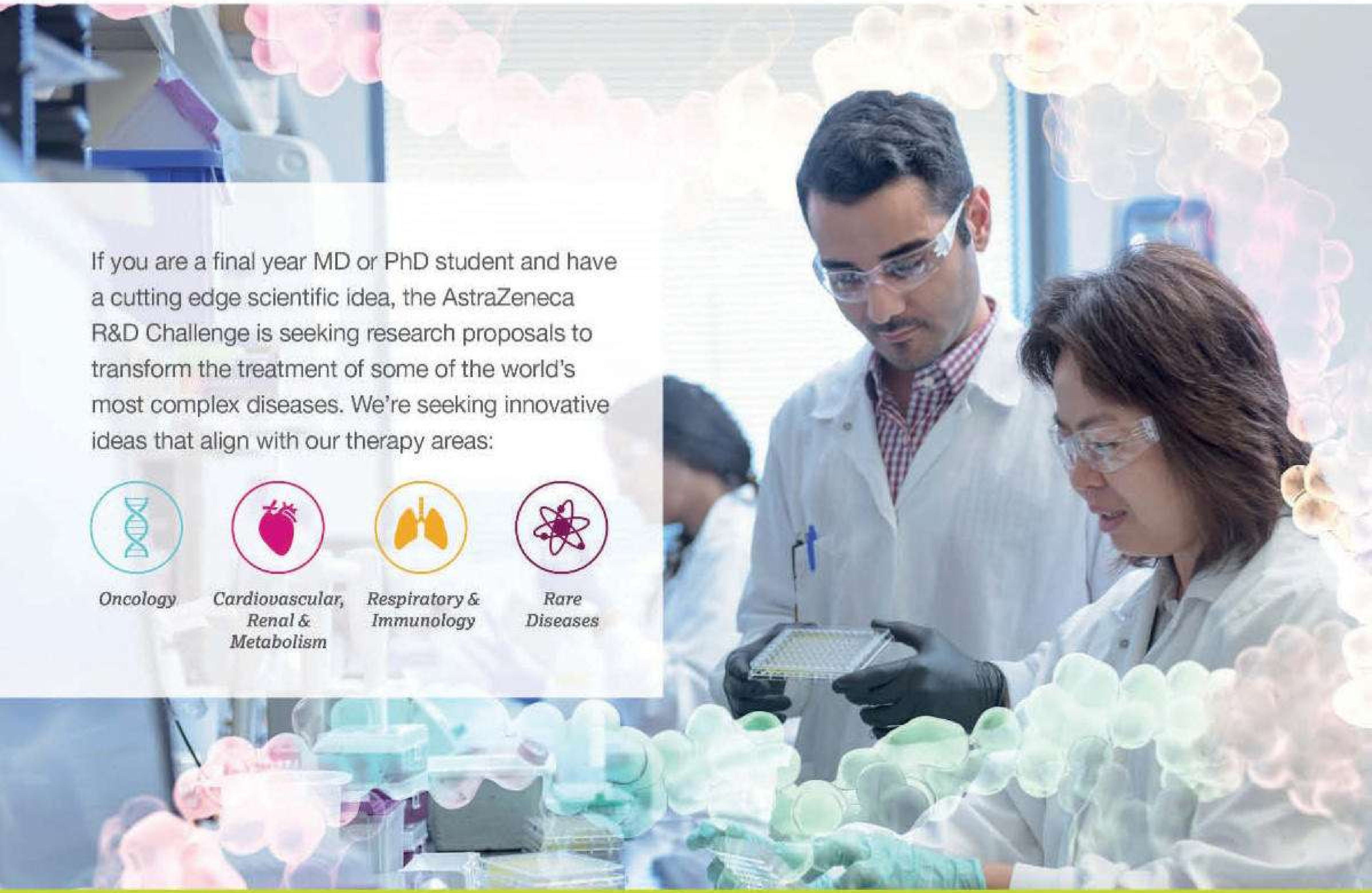

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The big if

An explosive result in particle physics could change everything – maybe

A SMALL discrepancy has sparked a big "if". Physicists who spent 10 years weighing the W boson, one of the fundamental particles that make up our universe, say it is 0.1 per cent heavier than expected (see page 8). What might be a rounding error in other fields of study could blow open the standard model of particle physics, one of our major theories for understanding, well, everything. If the measurement is correct, that is.

We have been here many times before. One of the most memorable cases saw a group of physicists working on the OPERA experiment announce in 2011 that they appeared to have discovered that particles called neutrinos could travel faster than light, breaking one of the seemingly immutable laws of the cosmos. They had spent months checking and rechecking their work and, unable to find an error, released it to the world with the scientific equivalent of "beats me, guv".

Physicists around the globe exploded with their own "ifs", dreaming up theories attempting to explain the anomaly, and, for a short while, everyone got very, very excited. Alas, six months later, the OPERA team made another announcement: the source of the puzzling data had been traced to a loose cable, which had slightly altered the calculations and produced the erroneous superluminality. The ifsters went back to the drawing board, theories relegated to mere fan fiction of reality.

> **"A universe of possibility hangs in the balance as physicists digest and dissect the findings"**

The W boson collaboration has spent even longer trying to poke holes in its own findings, and has come up short. Now, its members are asking for other physicists to help tear the work to shreds. Everyone wants the measurement to be right, because if it – or any of a handful of other anomalous measurements currently exciting particle physicists – is, it would spark a revolution in a field that has been somewhat languishing since the celebrated discovery of the Higgs boson in 2012. But realistically, the odds are in favour of some equivalent to OPERA's loose cable. Fresh eyes should help solve the thorny puzzle.

Still, if. A universe of possibility hangs in the balance as physicists digest and dissect the findings, which may well turn out to be the biggest result in decades. If. ▮

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Crypto bandwagon
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Health

Child hepatitis mystery

An unexplained rise in liver disease among young children is being investigated in the UK, reports **Clare Wilson**

DOCTORS are investigating a mysterious outbreak of liver disease in young children in the UK. So far, there have been 60 cases in England and 11 in Scotland of unexplained hepatitis, or liver inflammation, since the start of the year, most of them in children who are 2 to 5 years old. Case numbers in Wales and Northern Ireland haven't been released.

Although no child has died, a "small number" have needed a liver transplant, said the UK Health Security Agency (UKHSA) on 8 April. This means they will have to take drugs that suppress the immune system for the rest of their lives, which will leave them at risk of infections.

Hepatitis is often associated with specific pathogens, such as the hepatitis C virus, but it can be triggered by many other things. There have previously been small clusters of cases caused by the hepatitis A virus, which can be spread by faecal contamination of food or water. The hepatitis viruses A to E have all been ruled out in the current outbreak, though.

Finding the cause will require carefully investigating every case to see if they have factors in common, says Graham Cooke, an infectious disease specialist at Imperial College London.

The outbreak might have been caused by a rare delayed reaction to covid-19 infection, or by a different infection spreading after pandemic-related lockdown restrictions were lifted.

"There is probably a group of children who won't have been exposed to all those viruses they would normally be exposed to in early life," says Cooke. "With the easing of restrictions, a lot of other viruses are circulating that weren't able to circulate before.

The covid-19 vaccine can't be the cause, because it isn't being offered to children under the age of 5 in the UK.

Family doctors have been asked to watch out for children aged 16 and under who have symptoms of hepatitis, which include a yellow tinge to the skin known as jaundice, discoloured urine or faeces, itchy skin, fever, nausea and abdominal pain. ▮

Nuclear safety

Chernobyl spikes called into doubt

HIGH levels of radiation seen during the Russian capture of the Chernobyl nuclear power plant in Ukraine on 24 February were initially put down to tanks stirring up radioactive dust, but researchers now believe this contamination may never have happened. Instead, interference between wireless radiation sensors and unidentified military equipment may have been to blame.

Mike Wood at the University of Salford, UK, and his colleagues extracted data from automatic wireless monitoring systems at Chernobyl. He says the pattern of radiation spikes rules out a rolling convoy of military vehicles as it wasn't clustered around any particular route.

The team also calculated whether the radioactive material left in the soil from the plant's meltdown in 1986 was strong enough to cause the spikes and concluded that, even with conservative estimates, it wasn't (arXiv, arxiv.org/abs/2204.03157).

"We've hypothesised that the cause may well be to do with electromagnetic frequencies being used by the military, and it could be Russian or Ukrainian military around that time, actually interfering with the reception of data," says Wood.

The idea is plausible, but there is no way to verify the findings directly due to the war, says Bruno Merk at the University of Liverpool, UK. ▮

Matthew Sparkes

Particle physics

Shock result stuns physicists

The W boson is slightly heavier than we think it should be, according to data from Fermilab – and that could overturn our understanding of the universe, reports **Alex Wilkins**

A NEW measurement of a fundamental particle called the W boson appears to defy the standard model of particle physics, our current understanding of how the basic building blocks of the universe interact. The result will be heavily scrutinised, but if it holds true, it could lead to entirely new theories of physics.

"It would be the biggest discovery since, well, since the start of the standard model 60 years ago," says Martijn Mulders at the CERN particle physics laboratory near Geneva, Switzerland.

The standard model describes three forces: electromagnetism, the strong force and the weak force. Particles called bosons serve as mediators for these forces between particles of matter. The weak force, which is responsible for radioactive decay, uses the W boson as one of its messengers.

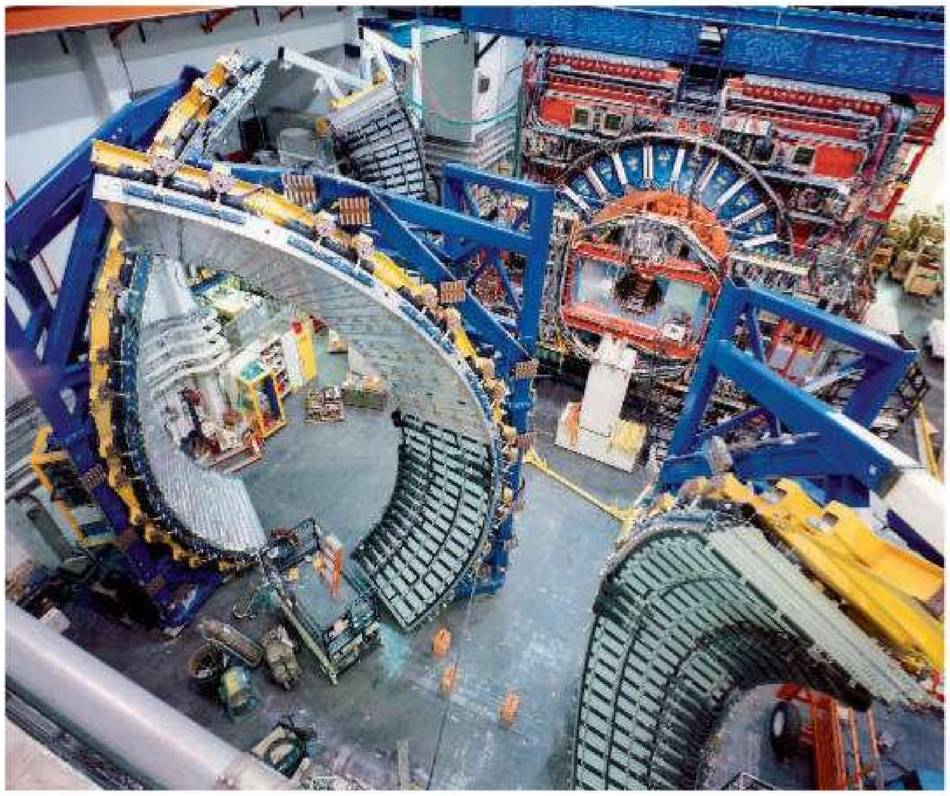
Physicists have tried to find the mass of the W boson with ever greater precision since it was first observed in 1983. These measurements have all broadly agreed with each other, an apparent confirmation of the standard model's validity.

But we know the model is wrong. It has no explanation for gravity, dark matter and the absence of antimatter in our universe, so physicists are on the lookout for deviant measurements that could lead to new theories.

Now, the Collider Detector at Fermilab Collaboration of around 400 scientists has a new figure for the W boson's mass. Using data from the Tevatron collider at Fermilab in Illinois, it puts it at 80.4335 gigaelectronvolts (*Science*, doi.org/hpsb).

The generally accepted mass is 80.379 gigaelectronvolts. While the discrepancy may seem small, the new value is the most precise so far, equivalent to measuring your body weight to within less than 10 grams. More importantly, its difference from the accepted value has a statistical significance of around 5 sigma, corresponding to a probability of about 1 in 3.5 million that measurements like this would show up as a statistical fluke.

Physicists normally use 5 sigma as the level of significance to count something as a "discovery", but the difference between the two measurements is even higher, at 7 sigma. This corresponds to about a 1 in 780 billion probability of seeing a result like this by chance. Ashutosh Kotwal at Duke University in North Carolina, who led the collaboration's analysis, says its members have done all the tests they can think of to confirm their extraordinary result, and it is now time for others to weigh in. "We think the answer is holding up to our own scrutiny," he says.



GRANGER/ALAMY

The Tevatron collider at Fermilab in Illinois, pictured in 1992

"It would be the biggest discovery since the start of the standard model 60 years ago"

The collaboration measured the boson's mass by smashing beams of protons and antiprotons together and analysing the particles produced in the collision. The analysis was so complex that the result took more than a decade to produce, after the Tevatron shut down in 2011, but its potential implications are huge.

"If the W boson mass is deviating that much from the standard model expectation... it's a huge deal," says Ulrik Egede at Monash University in Australia.

That "if" is important. Many physicists are excited but cautious. "We need first to understand the discrepancy between [this result] and all other experiments before we think about explanations from physics beyond the standard model," says Matthias Schott at CERN, who worked on a previous W boson measurement using data from the ATLAS experiment gathered at the Large Hadron Collider (LHC) up to 2018.

Figuring out the source of the discrepancy is tricky. W bosons quickly decay into other particles, either an electron and an electron neutrino, or a heavier muon and muon neutrino. Neutrinos are hard to detect, so the collaboration had to infer where they were from large amounts of data.

Measure twice

The 2018 ATLAS measurement for the W boson mass was the most recent to date, but it may also not be much help in solving the riddle. ATLAS used two beams of protons, rather than a second one of antiprotons, making the results harder to compare, says Kotwal.

If physicists can't find a problem with the collaboration's work, then the next step will be producing another measurement, which could come from three experiments at the LHC. "It's the only collider with a high enough energy to create W bosons," says Harry Cliff at the University of Cambridge. The LHC is gearing up for a new run this year after being offline since 2018, but Mulders says data collected for the CMS experiment during the previous run could yield a new W boson measurement by next year.

If the result is borne out, it might require new theories of physics to explain. Kotwal says that some variants of supersymmetry, which requires the existence of a whole new set of particles, might accommodate the higher W boson mass.

Despite the result taking 10 years to produce, Kotwal says this is just the start for understanding its significance, as physicists around the world get their hands on the data. "The science will be investigated and we will continue to think about it," he says. ▮

Astronomy

Ancient computer may have had its clock set to 23 December 178 BC

Leah Crane

WE MAY have figured out the date from which an ancient device often described as the first computer began its calculations. This device, called the Antikythera mechanism, was built sometime between the years 200 BC and 60 BC, and it was used to track time and predict the motions of celestial bodies.

A spiral shape inset in the back of the mechanism depicts a 223-month cycle called a Saros, which is based on the amount of time it takes for the sun, moon and Earth to return to the same relative positions and repeat a cycle of similarly timed solar and lunar eclipses.

Aristeidis Voulgaris at the Thessaloniki Directorate of Culture and Tourism in Greece and his colleagues used this to calculate a sort of starting date for the Antikythera mechanism, the "Day Zero" by which its calculations were calibrated.

"Any measuring system, from a thermometer to the Antikythera mechanism, needs a calibration in order to [perform] its calculations correctly," says Voulgaris. "Of course, it wouldn't have been perfect – it's not a digital computer, it's gears – but it would have been very good at predicting solar and lunar eclipses."

Based on our understanding of how the mechanism works and the inscriptions on it, the calibration date was expected to occur during a particular kind of solar eclipse in which the moon was located at the furthest spot in its orbit from Earth, a position called apogee. Voulgaris and his colleagues searched a NASA repository of eclipse calculations for unusually long-lasting eclipses, which occur when the moon is particularly far from Earth.

The longest such eclipse during the era when the Antikythera mechanism was built occurred in the small hours of 23 December 178 BC. When they looked further into this date, the researchers found that several astronomical events of cultural significance occurred then, including the winter solstice, which is engraved at the top left of the front of the mechanism, which Voulgaris says is a hint at its importance to calibration (arxiv.org/abs/2203.15045).

"This is a very specific and unique date," says Voulgaris. "In one day, there occurred too many astronomical events for it to be coincidence – this date was a new moon, the new moon was at apogee, there was a solar eclipse, the sun entered into the constellation Capricorn, it was the winter solstice."

The Antikythera mechanism, built at least 2080 years ago

ANCIENT ART AND ARCHITECTURE/ALAMY

However, other prominent researchers in the field have found a different calibration date.

"The eclipse predictions on the [device's back] contain enough astronomical information to demonstrate conclusively that the 18-year series of lunar and solar eclipse predictions started in 204 BC," says Alexander Jones at New York University. There have been four independent calculations of this, he says. "The reason such a dating is possible is because the Saros period is not a highly accurate equation of lunar and solar periodicities, so every time you push forward by 223 lunar months... the quality of the prediction degrades."

These other works relied on finding the one Saros period for which the mechanism's astronomical predictions would have been most accurate. However, the date that they found is in the summer, which would leave the question of why the winter solstice engraving is so prominent on the Antikythera mechanism's front plate unanswered, says Voulgaris. ▮

Cosmology

Astronomers have spotted the most distant galaxy ever

A GALAXY called HD1 may be the most distant object ever seen. Its astonishing brightness could be due to a huge black hole or the creation of extremely massive primordial stars, both of which confound our understanding of the early universe.

Fabio Pacucci at the Harvard-Smithsonian Center for Astrophysics in Massachusetts and his colleagues found HD1 by sifting through data from several of the most powerful telescopes available. Next, they observed it with the Atacama Large Millimeter/submillimeter Array in Chile. They found that HD1 is about 33.4 billion light years away, more than a billion light years further than the previous most distant object ever spotted. This is possible, despite the universe being only about 13.8 billion years old, because of the accelerating expansion of the cosmos.

HD1 is extraordinarily bright in ultraviolet wavelengths, meaning that whatever is producing its light is probably extremely hot. There are two possibilities: it hosts a burst of star formation much bigger than we would expect for the galaxy's relatively small size or it is home to an active supermassive black hole (*Monthly Notices of the Royal Astronomical Society*, doi.org/hpps).

If it is a starburst, HD1 would have to be producing about 110 times the sun's mass in stars every year. "It's a crazy number," says Pacucci. "One explanation is this galaxy might not be forming normal stars, but these primordial stars that are much more massive and much hotter than normal nearby stars." We have never seen such primordial stars before.

33.4

Distance in billions of light years to the HD1 galaxy

Or it could host an unexpectedly colossal supermassive black hole. "The observation of a 100-million-solar-mass black hole so early in the history of the universe would really be groundbreaking, because we really wouldn't be sure how to form this," says Pacucci. We are seeing HD1 as it was just 330 million years after the big bang, and it is unclear how a black hole could have become so big so quickly. ▮

Leah Crane

Russia-Ukraine war

Mobile phones as weapons

The way phones ping signals to communications towers is allowing Ukrainian and Russian soldiers to track the movements of opposition forces, finds **Chris Stokel-Walker**

MOBILE phones have captured much revealing and distressing footage of how the war is unfolding in Ukraine, but the technology is also being utilised by both Russia and Ukraine to eke out a military advantage.

The devices, whether they are the latest smartphone or older phones capable only of calls and texts, will be in the pockets of many Russian and Ukrainian soldiers, allowing each side to track the movements of opposition troops.

“We have a lot of data you wouldn’t have otherwise, and this data can be used to kill people”

Mobile phones broadcast signals to nearby communications towers, establishing a connection that allows people to make a call or go online. The pinging of these towers is frequently used by police forces in missing-person cases, with signals from three towers used to triangulate a phone’s location to within an area of about 1 square kilometre.

That principle is now being used by Ukrainian and Russian soldiers to track opposition forces. “You may as well paint a target on your back,” says Alan Woodward at the University of Surrey, UK.

A Russian system, called Leer-3, launches two drones that mimic mobile phone towers, picking up the location of more than 2000 phones within a 6-kilometre range. When it comes to the Ukrainian side, US officials told *The New York Times* in March that at least one Russian general has been killed after Ukrainian intelligence picked up one of his outgoing calls.

“Anyone who has access to the tower information can obviously triangulate positions, and with integration ISTAR [intelligence, surveillance, target acquisition, and reconnaissance] systems today, it can be a matter of moments from detection to launching a missile or firing a shell,” says Woodward.

Communication breakdowns and flawed plans mean the Russian army’s secure communication systems have been unreliable since its invasion on 24 February, forcing it to rely on mobile phones, believe military analysts. And many members of the Ukrainian army, which is made up of a considerable number of volunteers, may be unaware of the dangers of having phones in a combat situation.

“The bottom line is that personal mobile phones have no place on the battlefield,” says Woodward. Complex military radio systems use encryption and spread spectrum techniques, which alter the frequency of a radio signal by injecting random packets of noise, helping to avoid detection. Mobile phone technology, however, is easy to exploit.

Smartphones, in particular, use sophisticated global positioning systems (GPS). “Anything that transmits radio waves can be used to track people, and smart devices are dripping with metadata that can be used to target groups or individuals,” says Woodward.

That same metadata, such as a caller’s and recipient’s phone numbers, can also be used to bombard troops with propaganda. “We’ve seen many examples of soldiers from both sides getting calls and threatening messages,” says Yevgeniy Golovchenko at the University of Copenhagen, Denmark. “We’ve also seen family members getting calls as a way of intimidating and demoralising the other side.”

A Ukrainian soldier checks their phone in the outskirts of Kyiv, Ukraine

RODRIGO ABD/AP/SHUTTERSTOCK

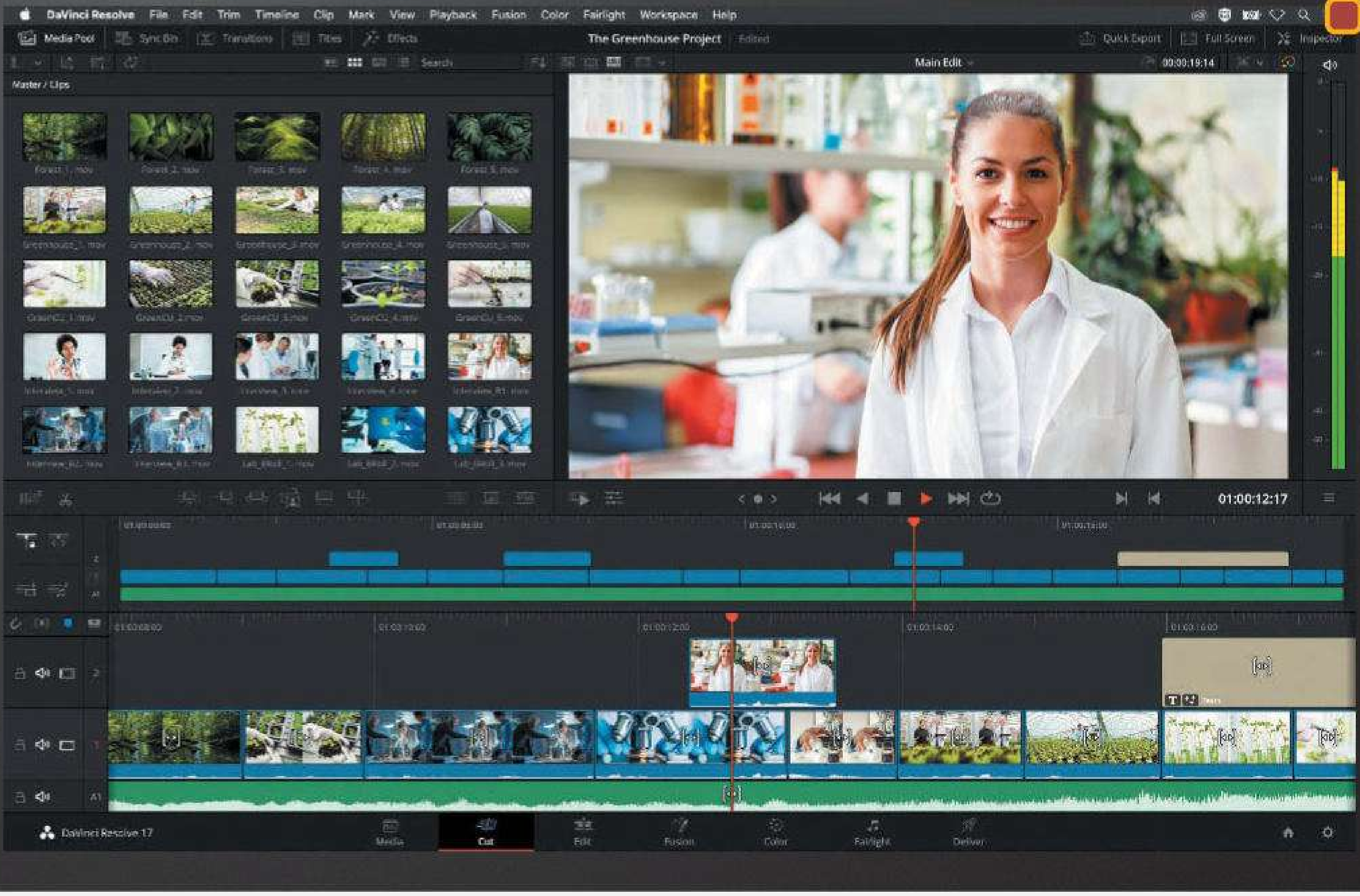
A similar method was used against NATO troops stationed in the Baltic states, according to Golovchenko, as well as against coalition forces in Afghanistan. Relatives of members of Danish forces stationed in Afghanistan received messages incorrectly telling them that their relatives were dead, waging psychological warfare designed to turn public opinion against the occupation of Afghanistan, he says.

Propaganda war

On 1 April, Ukraine’s intelligence service announced that 5000 text messages had been sent by Russia to the mobile phones of Ukrainian army officers and state security members in the north-eastern city of Kharkiv, urging them to give up their arms and surrender. The intelligence service claimed that Russia’s propaganda project cost $2000 a month.

Such strategies aren’t exclusive to Russia. An adviser to Ukraine’s minister of interior affairs has said the country is “regularly” sending similar messages to Russian soldiers, exhorting them to give up their military equipment in exchange for a cash reward. One Russian soldier, known as “Mischa”, has been promised $10,000 at the end of the war and the opportunity to apply for Ukrainian citizenship, according to the adviser.

These developments show just how important mobile phones can be in modern warfare. “Each soldier with a phone is a data point and generates data about themselves,” says Golovchenko. “All of a sudden, we have a lot of data you wouldn’t have otherwise, and this data can be used to kill people.” ▮



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Archaeology

Ancient Chilean tsunami scared local people away from coast for 1000 years

Michael Marshall

AN EARTHQUAKE as large as any in recorded history struck the coast of Chile about 3800 years ago, triggering a tsunami that caused devastation along 1000 kilometres of coastline.

In the wake of the tsunami, local hunter-gatherers began spending less time near the coast and moved cemeteries further inland, staying there for 1000 years or more, despite not having a system of writing to convey information about the disaster. It is a remarkable example of a society transforming itself to handle natural threats, say the researchers who studied the event.

The team, led by Gabriel Easton at the University of Chile in Santiago, spent years in the Atacama desert on the west coast of South America, gathering evidence of an ancient tsunami.

At multiple sites, they found a layer of distinctive sediment dumped by a tsunami. Radiocarbon dates from charcoal and shells in archaeological deposits directly overlying the tsunami sediment suggest it happened about 3800 years ago.

It is impressive that the team has found evidence over such a wide area, says Eugenia Gayo, director of Millennium Nucleus Upwell in Concepción, Chile. "It's robust."

The coast of Chile lies on a subduction zone, where one of the tectonic plates that make up Earth's surface is being forced under another. As a result, the region is prone to large earthquakes. However, the written record in this region is quite short, so it is unclear how big the quakes can be and how often the biggest ones occur.

"We propose that this earthquake was similar to the Valdivia earthquake that occurred in 1960 in southern Chile," says Easton. "This is the largest earthquake ever recorded in history." The Valdivia quake had a magnitude of about 9.5, and Easton's team says the tremor 3800 years ago was similar.

In theory, the Valdivia quake could have been a one-off caused by a very rare combination of circumstances, says Easton. But if a similar quake happened within the past 5000 years, that can't be true. "This is our proposal, that this area in northern Chile is capable to produce earthquakes of this size," he says.

People have lived in the Atacama for more than 12,000 years. However, Easton and his team documented major shifts that occurred around 3800 years ago. Archaeological sites near the coast show less evidence of habitation, suggesting people stopped going there or at least spent less time there. Furthermore, cemeteries were moved inland and uphill.

This new pattern of behaviour lasted a long time, with many coastal sites only being reoccupied between 1500 and 1000 years ago (*Science Advances*, doi.org/hpkh).

"This is kind of surprising, because people usually have a short memory for this kind of event," says Gayo. Maintaining the behaviour for 1000 years "is a lot", she adds. ▮

The Atacama desert has been occupied for 12,000 years

TIM WHITBY/ALAMY

Astronomy

Fast-moving stars probably come from other galaxies

THE speediest stars in the galaxy, moving at hundreds or even thousands of kilometres per second, are also some of the least well-studied. A study of 15 of these fast-moving objects has found that most of them probably came from dwarf galaxies devoured by the Milky Way in the distant past.

"This is the first time that a relatively large sample has been analysed and evidence has been shown that they are not from this galaxy," says Henrique Reggiani at the Carnegie Institution for Science in California. He and his colleagues used telescopes at Apache Point Observatory in New Mexico and Las Campanas Observatory in Chile to examine the light from 15 stars with relatively high speeds and learn their chemical compositions.

These stars aren't the very fastest in the galaxy, which are called hypervelocity stars and move with speeds in excess of 1000 kilometres per second, but rather a category called extreme-velocity stars, which move at hundreds of kilometres per second and are significantly easier to examine.

The researchers looked at the relative abundances of 19 elements in this set of stars. Stars from different galaxies tend to have unique combinations of these elements based on their formation histories, so this allowed the team to distinguish what kind of galaxies the stars were from.

Of the 15 extreme-velocity stars, the researchers found eight with chemical compositions that were definitively different from Milky Way stars, suggesting they formed elsewhere, while the rest were inconclusive (arxiv.org/abs/2203.16364).

"The exotic stars were probably born in smaller galaxies that were swallowed up by our own"

The exotic stars were probably born in smaller galaxies that were swallowed up by our own. Over the course of this messy galactic meal, the gravity of the Milky Way would have ripped apart the smaller galaxies, swinging them around and accelerating their stars to the high speeds we see today. ▮

Leah Crane

Welcome to our Signal Boost project – a page for charitable organisations to get their message out to a global audience, free of charge. Today, a message from **The Forgotten Diseases Research Foundation**

Emily and Sam have ataxia-telangiectasia, a rare disease we study

Help for rare diseases

WHAT'S THE ISSUE?

Worldwide, an estimated 263–446 million people have a rare disease – as much as 6% of the planet's population. Most of these diseases are chronic and uncurable. Unfortunately, the large number of rare diseases means that individual conditions don't get a lot of attention and can become forgotten. Getting a diagnosis is difficult and treatments frequently don't exist beyond managing symptoms.

WHAT ARE WE DOING?

First, we're creating a big database of information on rare diseases. We think there's a lot to learn about relationships between different diseases. There are thousands and thousands of published papers describing different diseases, yet there's no central repository where all that information is assembled in one place and set up so that it can be queried.

We hope that the database we're creating will help reveal pathways shared between different diseases. For example, is there a common abnormality leading to poor growth? Alternatively, why is it that some patients with an immunodeficiency syndrome suffer from frequent infections, but others rarely get sick – even though the same gene is affected in all patients? What can we learn by combining as much information as possible in one place? We already have 77 different conditions in our database and have made basic analytics software to query the data. Our software is free to use on our website.

We understand that this project is enormous, but we're hoping that one day it will become an important source for information for rare disorders.

Second, we're making tools that can be used in clinical trials – such as syndrome-specific scales that can be used to sort patients into different severity groups. It's important to put trial participants into similar groups, because when groups are too different, it's possible that the effects of a drug candidate get blurred and are missed. Tools like these exist for common diseases, but they're still unusual in rare diseases. Yet they're very important.

Want to help?

We're a small charity and our resources are limited. Your contributions can help us add new diseases to our database and/or add new functions to our software.
For more information, visit our website at www.forgottendiseases.org.

Field notes Climate change

The Helsinki neighbourhood leading the way to zero-carbon cities

Adam Vaughan

LEV KARAVANOV/ALAMY

JUSSI HELLSTEN/CITY OF HELSINKI

New apartment buildings and a robotic bus in Kalasatama

A NEIGHBOURHOOD in the shadow of a coal power station on the outskirts of Helsinki, Finland, might seem an unlikely place to evangelise about its environmental credentials. But here in the former cargo port of Kalasatama, a 31-year megaproject is under way to build a model green urban district that should eventually be home to 30,000 people.

About 9000 have already moved in. "It's getting better and better by the day," says Hetta Huittinen-Naskali, who has lived in Kalasatama for four years.

The neighbourhood is billed by city authorities as a test bed for new ideas that might be rolled out to the rest of the capital: last year saw a pilot driverless bus project and robots delivering food to older residents. Perhaps most importantly, the area is grappling with ways to reduce its reliance on fossil fuels to meet Helsinki's goal of absolutely zero carbon emissions by 2040.

The Hanasaari coal plant overlooking the school attended by Huittinen-Naskali's daughter is due to close in a year's time, a step towards that target. Another coal plant elsewhere in the city will shut a year later. High gas prices and the invasion of Ukraine by Finland's neighbour, Russia, haven't changed the phase-out plans, says Anni Sinnemäki, Helsinki's deputy mayor. "What it has meant to us is to accelerate the climate work, to accelerate those measures which diminish our dependency on Russian energy."

2040

Helsinki's target year for achieving zero carbon emissions

Walking through Kalasatama's mix of new high-rise towers and streets of town houses and flats clustered around courtyards, it is clear that these environmental aspirations go beyond energy. A big appeal for residents such as Paavo Tikkanen is the metro station that takes you to Helsinki's centre in 10 minutes. Shops, schools and homes are densely packed, in the spirit of the "15-minute city" concept of essentials being within 15 minutes of walking or cycling.

City planners have tried to deter car ownership, which is relatively high in Helsinki due to the capital's low density, by limiting car parking spaces. Pasi Rajala, head of master planning for Helsinki, says there are about 50 per cent fewer spaces per resident in Kalasatama than the city average. Nonetheless, many of the residents *New Scientist* spoke to own a car. "We have political parties that don't like that we [restrict] the private car, so it takes time," says Rajala.

Kaisa-Reeta Koskinen, head of the city's climate unit, says there will have to be a shift away from driving to reach zero emissions. "It's not enough that you change your car to electric," she says.

There is one vehicle that is largely absent on the neighbourhood's roads: rubbish trucks. Residents instead sort their waste and dump it into one of five hatches built in and around homes, where it is whisked away by vacuum to an underground system for recycling or burning to generate energy.

The fabric of most buildings here has been built to demanding energy efficiency standards, and a small number of solar panels dot the roofs of some. Tikkanen proudly says that he rarely turns on his radiators. Almost all the homes are kept warm with a heat network, where a central boiler pipes hot water to many homes, and in some cases several streets. This is an efficient option, but one that is overwhelmingly powered by coal and gas today.

The scale of new construction is dizzying: 1 in 7 new homes built in Helsinki each year is in Kalasatama. More families are moving in than expected – Jenni Tyynela, a teacher, says her kindergarten in the area has a waiting list. Two more are coming, one being built with a timber frame erected under a huge tent. Officials hope that more buildings here will be made from wood, locking away carbon and offering a lower-emission alternative to cement and steel. Climate experts in the UK are also pushing to see more timber buildings.

By the time Kalasatama is complete, 18 years from now, Sinnemäki hopes Helsinki will start being "carbon negative", removing carbon dioxide from the atmosphere. The district has little room for more trees, so this could mean building facilities that extract CO_2 directly from the air, but Koskinen concedes that the details have yet to be worked out.

Still, she is clear about the near term: burning fuel isn't the future. Plans to expand biomass energy generation have been scaled back and will now stop at just one biomass plant. Koskinen says it is "not a sustainable solution", a view that many researchers agree with. Instead, electrification of heating is the answer, she says. That might be small heat pumps, electrical boilers or pioneering options such as a mooted seawater heat pump.

City planners shouldn't wait to have all the answers on climate change, says Koskinen. "Sometimes, we just have to decide something. Because we cannot wait." ▮

Analysis Space industry

Is Amazon going to dominate space? Its massive order for rocket launches over the next five years has gobbled up much of the global market, but it could spur new opportunities, says Paul Marks

A MULTIBILLION-dollar booking of satellite-launching rockets has suddenly made Amazon one of the busiest space-flight operators. Will the tech giant's attempt to corner much of the launch market quash the ambitions of smaller satellite operators or could this light the fuse on a new generation of rocket firms?

On 5 April, Amazon astonished the space industry by revealing that it had placed the biggest set of orders for orbital rockets in space-flight history, buying 83 launches over the next five years to place more than 3000 of its Project Kuiper internet satellites into low Earth orbit, at a rumoured price of $10 billion.

Like SpaceX and OneWeb, Amazon is hoping to provide global internet connectivity, but the firm is currently way behind its competitors. "Kuiper is playing catch-up to [SpaceX's] Starlink and OneWeb, which are already mid-way deployed," says Greg Sadlier, a London-based analyst at consultancy Know.space.

But the sheer size of the rocket orders Amazon has placed – with United Launch Alliance, Arianespace and Blue Origin – is raising questions over just how much launch capacity will remain for other would-be satellite operators. Sanctions following Russia's invasion of Ukraine have seen Soyuz rockets ruled out for satellite launches by Western firms – even OneWeb, formerly carried on Soyuz, is now being flown by SpaceX – so for those not booked on SpaceX Falcon 9 flights, what are the options?

"If Amazon has kind of absorbed most of the launch capability, what's left for everybody else? Where do other operators go to launch their systems?" asks Hugh Lewis, a space scientist at the University of Southampton in the UK. This could be of particular concern for operators wanting to replace remote sensing and Earth observation satellites at the end of their lives, he says.

An artist's impression of a United Launch Alliance rocket

AMAZON

One option could be to buy a ride on rockets launched by the Japanese or Indian space agencies, but this generally only works if customers are happy for their satellites to be placed in the same orbit as the primary payload, which is usually dictated by the government. China also has its own rockets, but generally solely offers ride-shares to domestic firms.

Yet all is not lost. A raft of companies are developing a new generation of rockets designed to launch smallsats – those in the sub-1500-kilogram range. The NewSpace Index, which tracks smallsat launchers, lists more than 180 potential vehicles, though more than 80 per cent are still in the concept or development stages.

Companies entering the smallsat rocket fray include start-ups Astra and ABL Space Systems in the US, and Orbex and Skyrora in the UK. Amazon is already involved in this arena as well: it is set to launch two test versions of its Project Kuiper internet satellites on an ABL Space Systems RS1 rocket later this year.

So through its massive launch order, Amazon may have done the smallsat rocket-makers a favour by forcing other operators to seek a ride elsewhere. It is now up to these emerging businesses to come up with the goods. "They will need to rise to the supply challenge to meet that demand," says Sadlier. ▮

Animal behaviour

Female wētās have two sets of genitals and eat ejaculate

FEMALE short-tailed ground wētās, a cricket-like insect found in New Zealand, consume male ejaculate after sex to give them enough energy for parenting.

Darryl Gwynne and Jessica Browne at the University of Toronto in Canada also recently discovered that the mating success of female *Hemiandrus pallitarsis* depends on the size of their secondary genitals.

To mate, a male and female wētā first drum their abdomens on leaves to signal readiness. Things then get weird when they pair off, due to the female's two sets of genitals. Her primary genitals receive and store sperm, while her secondary genitals help collect extra ejaculate in the form of a "food gift".

The secondary genitals are shaped like a bent elbow with a forked tip, and the male uses his genitals to grab onto them while he deposits the extra ejaculate on her abdomen. This doesn't contain any sperm but is full of nutritious proteins. After mating, the female eats it. Gwynne believes the insects do this to sustain themselves for the next six months while they go underground to care for their eggs.

"She doesn't eat at all during this time, probably because there's no food underground and she can't leave her eggs in case a natural enemy comes and does something nasty to them," he says.

The team collected 58 females from two sites on New Zealand's North Island and found through the DNA of their stored sperm that those with longer secondary genitals had mated with more males (bioRxiv, doi.org/hpqp).

"There's no food underground and she can't leave her eggs in case a natural enemy comes"

"Males may prefer to mate with females that have longer secondary genitals because it signals they're of higher quality and able to provide better maternal care, which leads to more offspring," says Browne.

Unfortunately, females don't receive much of a reward for the six months they spend devoting themselves to their offspring. Once their young go off into the world, females promptly die. ▮

Alice Klein

10 days | 17 September 2022

Science of the Incas: Peru

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Immerse yourself in the Inca civilisation's most important archaeological sites, science and history while exploring Peru's beautiful Sacred Valley. Of course, you will visit Machu Picchu, as well as get to the heart of how Hiram Bingham "discovered" it and several other Inca sites just over 100 years ago.

But the story of the Incas is so much more than just Machu Picchu. They arranged their religious sites, or huacas, along a system of astronomically and calendrically informed lines, called ceques, centred on the ancient city of Cusco, a further highlight of this trip. As the tour will explore, this "calendar on the ground" affected the location of Inca towns, their ceremonies, the social interactions of their elite groups and their highly advanced architecture.

This unique expedition will be accompanied throughout by anthropologist, explorer and Emmy award-winning filmmaker Peter Getzels, and further benefit from the expertise of Jean-Jacques Decoster, professor of anthropology at the Universidad Nacional San Antonio Abad in Cusco. Learn how the Incas developed a complex society and used their extensive grasp of science and technology to expand rapidly, and marvel at their mastery of stone-cutting, astronomy and mathematics to create buildings for living and worshipping in and systems of irrigation and aqueducts to precisely control water for high-altitude farming on steep slopes.

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Highlights

- Machu Picchu UNESCO World Heritage Site
- Multiple archaeologically important Inca sites and museums
- Two days' assisted trekking to beautiful and remotely located Inca sites.
- Expert accompaniment throughout by anthropologist and filmmaker Peter Getzels
- Guest lectures and walking seminars from Jean-Jacques Decoster and local guides
- The Inca capital city of Cusco, also a UNESCO World Heritage Site
- Inca cosmology and stargazing evening
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Briefing

How LFTs really work

As England changes its guidance around testing for covid-19, **Clare Wilson** looks at how lateral flow testing works

DOMINIKA ZARZYCKA/NURPHOTO/GETTY IMAGES

A woman takes a throat swab for an at-home covid-19 test

A RECORD percentage of covid-19 tests for people in England and Wales are positive. Here's what you need to know about how lateral flow tests work, why symptoms may linger even if a person is no longer testing positive, and how long you can test positive after you have recovered from your symptoms.

What is the current advice in the UK if you have covid-19?

Although people in England no longer legally have to self-isolate if they have covid-19 symptoms or test positive, it remains UK government advice that they should try to do so for at least five days, although they can be infectious for up to 10 days and so should avoid contact with people who are at higher risk for that period.

"The focus of this new phase [of the pandemic] is on protecting those who are most at risk from the virus," said a spokesperson for the UK Health Security Agency (UKHSA) in a statement. In Scotland, Wales and Northern Ireland, people should only stop isolating before 10 days if they have two negative results from a lateral flow test (LFT) over two days.

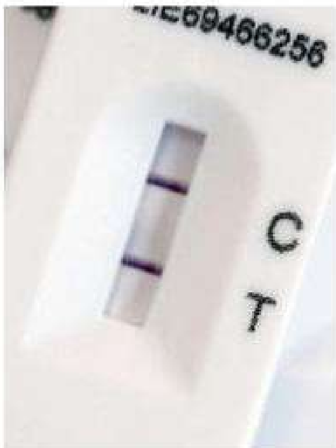
In England, people are no longer advised to take LFTs to check when they become negative, and the tests are no longer free for the general population, although they can be bought at pharmacies. "The fact that legally it's not enforced anymore doesn't mean that people shouldn't still be careful," says Christopher Chiu at Imperial College London.

How have the rules in England changed for children?

The UKHSA no longer advises people under 18 to get tested for covid-19, unless it is on a doctor's advice. For those who do have a positive test, the recommended self-isolation period has been cut to three days after the day the test was taken.

"There is some evidence that children have a shorter duration of illness compared to adults," said UKHSA head Jenny Harries in a statement. "Ideally, children would return to school as soon as they turn lateral flow negative," says Iain Buchan at the University of Liverpool in the UK. "But at some point, political decisions need to be taken, over cost and priorities. Prioritising children's education and social development is important."

A positive result on a home lateral flow test



RICHARD HARDING/ALAMY

How do I count how long I have been infected?

The first day someone experiences symptoms or tests positive is counted as day zero. Someone trying to self-isolate until day five would actually need to stay home for six days.

Does the intensity of a line on an LFT reveal anything?

Lateral flow tests aren't approved to be used in this way, but people usually see the line on their test changing in intensity from faint to dark, and back to faint again, over the course of their infection. Some studies do show that the intensity of the line correlates with the amount of virus particles present in the person's nasal fluids.

"These tests actually are very quantifiable based on the darkness of the line," says Michael Mina at eMed, a US testing firm.

But even if the line is faint, there must still be replicating virus present in someone's body in order to be making enough protein that it gives a positive result.

Why might I still have symptoms even though I test negative?

Some symptoms may continue after someone is no longer infectious.

"In general, people have a cough for a long time," says Al Edwards at the University of Reading in the UK. "There are two reasons for having a cough. One is because you're infected, and that's causing damage, and that makes you cough. The other reason for having a cough is because your respiratory tract gets damaged by the viral infection and it's healing."

"There is some evidence that children have a shorter duration of illness compared to adults"

Can you have false positives from LFTs after a covid-19 infection?

Schools in the UK are being told by health services that children may have a positive LFT for up to three months after their infection. This is "theoretically possible, but it would be very unusual", says Buchan, who ran the first mass community study of LFTs in Liverpool.

LFTs test for virus protein, which is produced by replicating virus, and so are less likely to give a false positive than PCR tests. PCRs detect the virus's genetic material, fragments of which can remain for several weeks after there is no viable virus left. ▮

Alien life

The plan to challenge aliens to a very slow game of chess

Matthew Sparkes

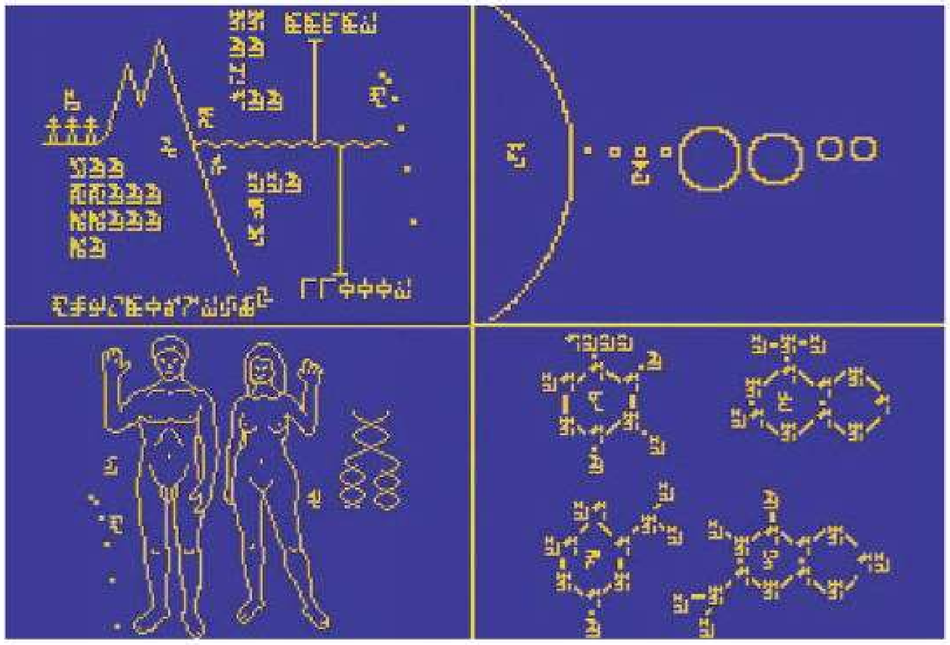
A GROUP of scientists has designed a new message to beam across the galaxy in the hope of striking up a conversation with an alien civilisation. The team says starting a game of chess would be a logical next step if we get a reply, but communicating a move in the game would take tens or hundreds of thousands of years.

There are many active projects searching for extraterrestrial intelligence, but there have also been some attempts to message one, even leading to the creation of a non-profit organisation called Messaging Extraterrestrial Intelligence (METI). In 1974, the Arecibo radio telescope sent a 1679-bit message towards globular star cluster M13, which sits 25,000 light years from Earth. Pioneer and Voyager spacecraft also took discs with information about humans outside our solar system.

Jonathan Jiang at NASA's Jet Propulsion Laboratory, who co-authored the new Beacon in the Galaxy (BITG) message, says we now have the technology to provide more detail. BITG includes Earth's location within the galaxy, relative to clusters of stars, as well as information on the time the message was sent relative to the birth of the universe. In all, the message contains 204,000 bits, more than 121 times as much data as the Arecibo transmission (arxiv.org/abs/2203.04288).

The team says that aiming the message at a star cluster between about 6 and 20 light years from the centre of the Milky Way would give the best chance of a reply. Jiang says there are no plans to send the message, but the team hopes the proposal will encourage global discussion about how we eventually reveal ourselves to galactic neighbours. "In recent years, we have found thousands of exoplanets, compared to 1974, when we did not know if there were planets outside our solar system," he says.

Details of the message that scientists could send into space



JIANG ET AL./NASA JET PROPULSION LABORATORY

Philip Rosen, a retired engineer and co-author of the paper, says that if we receive a reply, sending the rules of chess and beginning a game could "provide insights into thought processes of logic, strategy and planning" of the civilisation.

Anders Sandberg at the University of Oxford says that previous attempts to message aliens have been few and far between because of the "giggle factor" around the idea in scientific circles, challenges in sending a strong enough signal and also because of "vigorous debate" about whether it is wise to do so. "Some people think that it's really risky to say where we are because that gives an address to where to send the war fleet."

He believes the risk is negligible, but says it would be wise for humans to "become better at making joint decisions as an entire species" before attempting galactic communication.

Douglas Vakoch at METI says the message has merit, but a variety of transmissions should be sent, because some approaches may be impenetrable for an alien species. ▮

Animals

Male crossbills grow redder feathers when they exercise

IN A kind of post-workout glow, male crossbills that work harder when flying grow redder plumage.

Many animals acquire their bright colours from compounds in their diet. Male common crossbills (*Loxia curvirostra*) take in yellow carotenoid pigments from their food and convert the pigments into vibrant, red ketocarotenoids, which are stored in the feathers.

But research in the 1950s showed that male crossbills kept in cages began growing only yellow feathers when they moulted. This, plus more recent research suggesting that yellow-to-red carotenoid conversion may occur in the inner membrane of a cell's energy-generating mitochondria, made Carlos Alonso-Alvarez at the Spanish National Research Council in Madrid and his colleagues wonder if red feathers were partially a result of exercise.

The team captured 295 male crossbills in central Spain and measured their colour, size and weight. To make flight a bit more metabolically taxing, the researchers clipped some wing feathers from half the crossbills. They also plucked feathers from all of the males' rumps and released them back into the wild.

When a few dozen of the birds were recaptured in the following months, they had regrown their rump plumage – and the feathers growing back on the clipped birds were redder than those on their unclipped counterparts. The clipped birds also lost weight, which the researchers attribute to the added strain of flying while missing some important feathers (bioRxiv, doi.org/hpnd).

WILDLIFE GMBH/ALAMY

A male common crossbill (*Loxia curvirostra*) with bright red feathers

This suggests exercise affects feather colour. Red feathers may be a signal that depends "on the quality of the individual, but independent of resources and cost of production", says Alonso-Alvarez. ▮

Jake Buehler

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Briefing

UK jumps on crypto bandwagon

The UK government is going to launch a range of NFTs, and reactions to the plan have been mixed, reports **Matthew Sparkes**

What is an NFT?

A non-fungible token (NFT) is a cryptographic claim of ownership, similar to the deed to a house, that is encoded into a blockchain, meaning that it cannot be altered. Typically, it is used to denote ownership of something that exists elsewhere. For instance, artists can sell ownership of a digital artwork as an NFT. Anyone is free to download a copy of that artwork, but the "owner" is the person who has access to the appropriate NFT.

Why is the UK government getting involved?

John Glen, the economic secretary to the Treasury, who announced the plan in a speech on 4 April, said that the government wants the UK to be "the very best place in the world to start and scale crypto-companies". The NFTs, which will be created by the Royal Mint and launch later this year, will be an "emblem of the [UK's] forward-looking approach", said Glen.

Doesn't the Royal Mint make coins?

The Royal Mint produces the British pound coins, but also sells collectable items such as medals and commemorative coins. A spokesperson said in a statement that NFTs were a "natural progression" for the organisation.

JEREMY SUTTON-HIBBERT/ALAMY

The Royal Mint produces physical pound coins and will now make NFTs

What will NFT buyers get?

At the moment, it is unclear what exactly the owner or owners will be buying, and whether they will get any concrete ownership rights. The Treasury said only that an NFT was being developed, while the Royal Mint told *New Scientist* that it would actually be a "range" of NFTs. Neither would give more details on what the NFTs would involve, how much they would cost or how many there would be.

What else is the UK planning to do?

Glen said the government is planning to allow stablecoins – cryptocurrencies that are pegged to the value of existing currencies, rather than fluctuating with market forces – to be used for payments. But there is little detail yet on where and how, and anyone is free to use them as payments already. The government will also regulate the trading of other cryptocurrencies like bitcoin.

Are all UK officials onboard?

Not everyone is keen on cryptocurrencies. "Never in the history of commerce has there been an invention as hyped and misunderstood," said Glen. On the same day, Bank of England governor Andrew Bailey said that cryptocurrencies are the new "front line" in criminal scams.

What do other people think?

Alex Moss at FireCask, a UK marketing agency that works on NFT launches, says it is a move that will allow companies such as his to thrive. "This is a great step towards mass adoption," he says.

William Entriken, one of the authors of the NFT protocol for the Ethereum blockchain, says that the plan may help the UK government tax cryptocurrencies. "The role of good government probably should include reviewing trillions of pounds worth of unregulated assets," he says.

Are there any downsides?

The government admitted in its announcement that criminal use of cryptocurrencies is an issue, but that cryptocurrencies operating in the UK are now subject to money laundering regulations. It has also promised to look at the vast amounts energy consumed by cryptocurrencies. ▮

Neurology

Map created of brain changes from pre-birth to old age

A MAP of how our brain changes throughout our life could aid in diagnosing neurological conditions.

"It's the first time that anyone sort of stitched together these developmental patterns really, throughout the whole lifespan, going from even pre-birth to old age," says Richard Bethlehem at the University of Cambridge.

Questions about the variation in possible brain size across humans haven't been addressed that well in previous studies, says team member Jakob Seidlitz at the Children's Hospital of Philadelphia. The team analysed 123,984 MRI scans from 101,457 humans, from a 16.5-week fetus to 100-year-olds, from more than 100 studies.

Brain size increased from 10 per cent to 80 per cent of maximum volume from about 4 months old to 3 years old, peaking at 1066 cubic centimetres around 11 years old, then gradually declining. The average thickness of the cortex, the brain's outer region, peaked at 1.7 years old (*Nature*, doi.org/hpkn). Cortex thinning has been linked to Alzheimer's disease, suggesting early brain development may influence the risk of the condition.

The map could one day act as a reference for standard brain growth, similar to paediatric growth charts, helping better track the onset of neurological conditions. "I am excited to learn about this colossal first step towards generating brain development charts that will, in the future, facilitate more accurate and early diagnosis of atypical developmental patterns," says Vaidehi Natu at Stanford University in California.

"The map could one day act as a reference for standard brain growth, similar to paediatric growth charts"

In the meantime, we need to study brain scans of a more diverse population. "What we have in our study is a majority of North American, European ancestry, city-based, relatively well-off individuals that tend to take part in these research studies," says Bethlehem. "Expanding that to have a more representative nature would make it more clinically relevant." ▮

Carissa Wong

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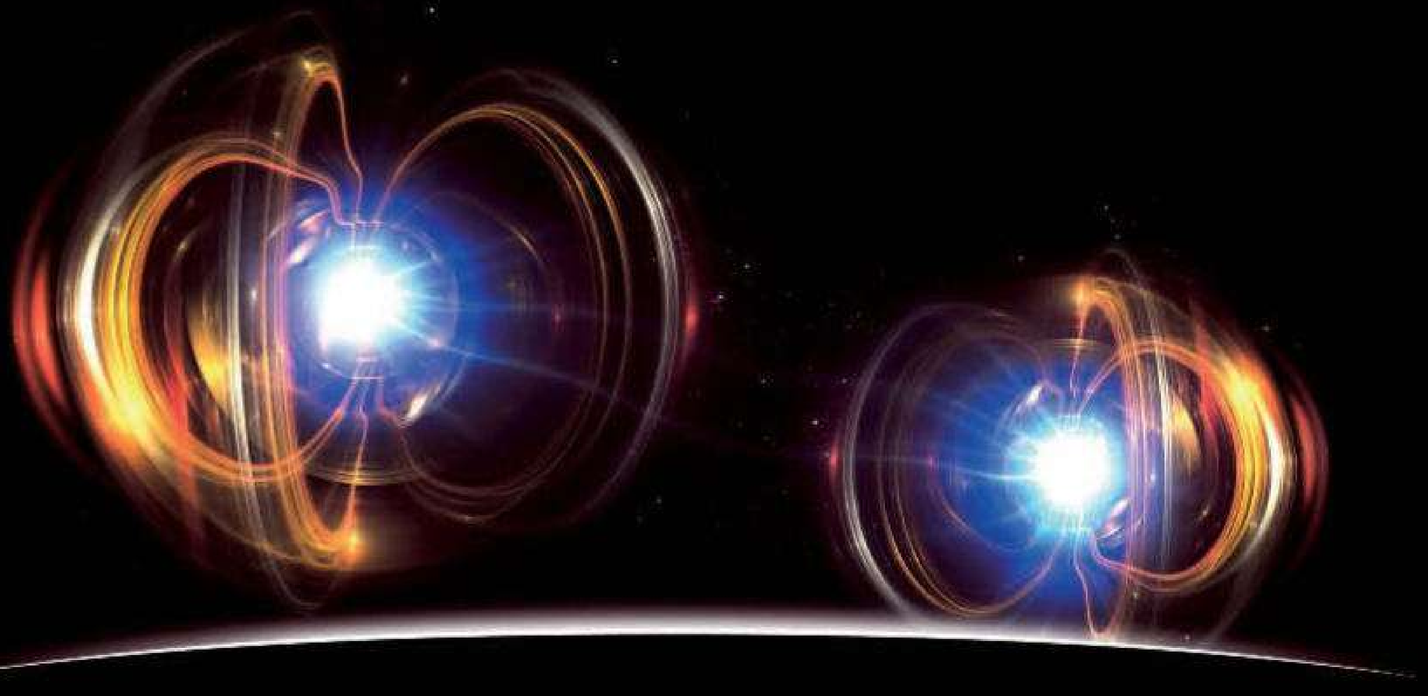

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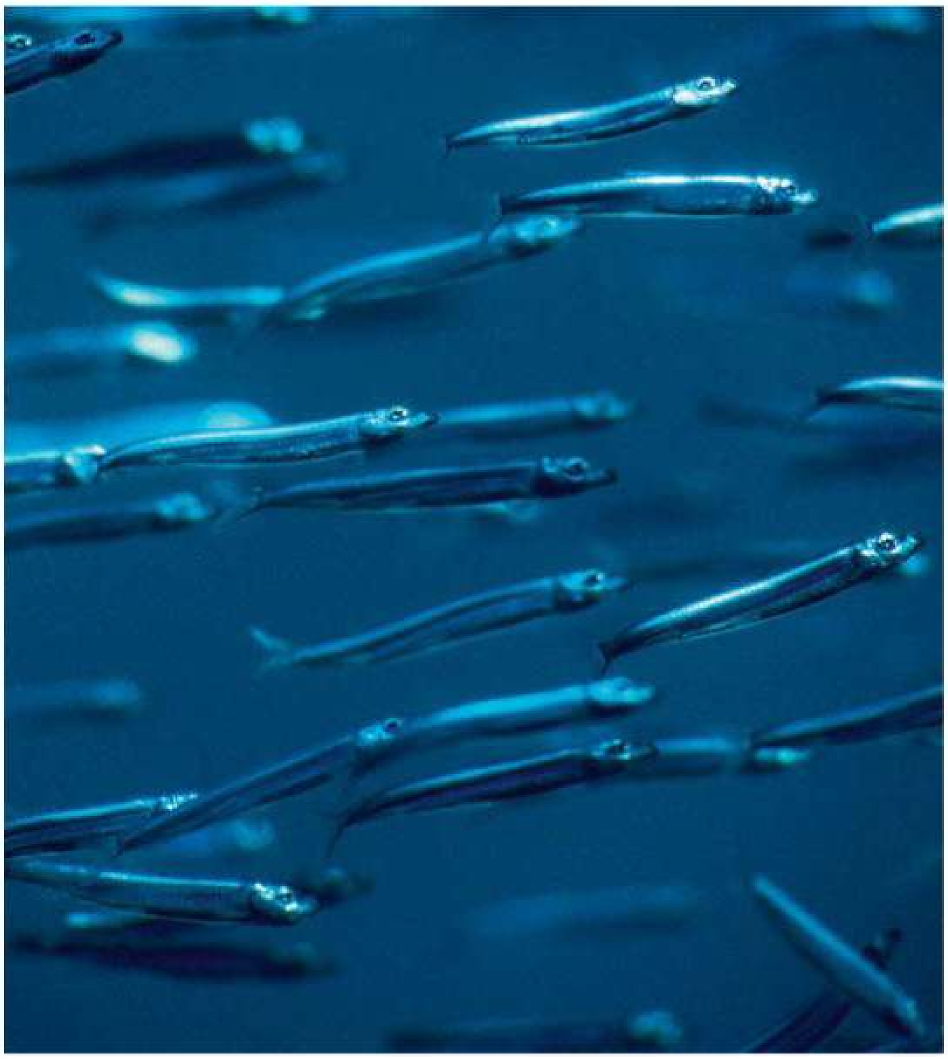


JUERGEN FREUND/NATUREPL.COM

Oceans

Anchovies stirring up the sea may alter ocean mixing

SHOALS of breeding anchovies may be stirring the ocean off the coast of Spain. The finding suggests that fish could play a bigger role in ocean mixing than previously believed.

Bieito Fernández Castro at the University of Southampton in the UK and his colleagues measured the speed of ocean currents off the Galician coast, in north-west Spain, for two weeks in July 2018.

The researchers initially planned to study the effects of vertical ocean mixing on marine life in various parts of the ocean, but quickly changed tack when they saw a major unexplained rise in turbulence in their first few nights at the same spot. Ocean mixing is largely thought to be controlled by wind and tidal energy, but neither factor could explain this night-time rise, says Fernández Castro.

The researchers moored their vessel at the same spot for two weeks and monitored turbulence 24 hours a day. They found that it increased every night by a factor of between 10 and 100. Using an echo sounder, the researchers discovered that anchovies were gathering near the boat every night. Investigating further and finding anchovy eggs led the team to conclude that the fish were gathering there to reproduce (*Nature Geoscience*, doi.org/hpr6).

"The possibility that biology contributes to ocean mixing is quite controversial," says Fernández Castro. "But we were able to measure and quantify it in this case. What we don't know yet is how important it is for overall ocean circulation."

Jason Arunn Murugesu

Technology

Solar panels that can work at night

MODIFIED solar panels that work at night generate enough power to charge a phone, bypassing the need to store energy in batteries.

In simple terms, solar electricity is generated when the sun radiates energy towards a relatively cool solar panel. The panel consists of solar cells, made from layers of a semi-conducting material, usually silicon. When light shines on this material, it generates a flow of electricity.

At night, however, solar panels radiate heat in the form of infrared light to outer space, which is about -270.15°C, as heat travels towards lower temperatures. As the atmosphere is invisible to infrared light, this makes the solar panel cooler than the surrounding night air, a temperature difference that can be used to produce electricity.

To do this, Shanhui Fan at Stanford University in California and his colleagues modified an off-the-shelf solar cell by adding a thermoelectric generator, a device that produces currents from temperature differences.

"The solar panel turned out to be a very efficient thermal radiator," says Fan. "So, at night, the solar panel can actually reach a temperature that's below the ambient air temperature, and that's a rather unusual opportunity for power harvesting."

When pointed at a clear night sky, the modified solar cell generated a power output of 50 milliwatts per square metre (*Applied Physics Letters*, doi.org/hpnw). This is just 0.04 per cent of the power output of a regular solar cell during the day, but it is enough to enable low-power devices to function, such as a phone charger or a low-wattage LED light.

"The nice aspect about this approach is that you essentially have a direct power source at night that does not require any battery storage," says Fan. **Alex Wilkins**

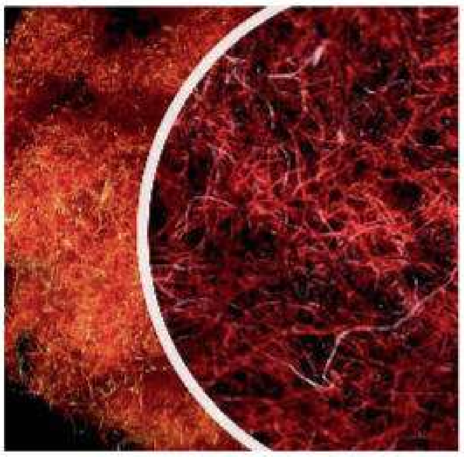
Environment

Fabric conditioners cut microfibre leak

TUMBLE-DRYING clothes releases microfibres, but switching your fabric conditioner and using a dryer sheet could cut this.

Microfibres (pictured) are tiny strand-like particles that detach from our clothes during washing and drying. They can end up in the air, soil and water and may be harmful to humans and wildlife.

Neil Lant at consumer goods company Procter & Gamble and his colleagues washed loads of laundry containing 10 cotton and 10 polyester T-shirts using various brands of detergents, fabric conditioners and dryer sheets that are popular in Europe and North America. They then dried these clothes in vented tumble dryers, which expel moist warm air to the outside air through a pipe, and measured the amount of microfibres that were released.



LANT ET AL., 2022, PLOS ONE, CC-BY 4.0

They found that ordinary fabric conditioners reduced microfibre emissions by a maximum of 22 per cent, depending on the product and dosage, but anti-wrinkle fabric conditioners cut them by up to 36 per cent. Using an anti-wrinkle fabric conditioner and a tumble dryer sheet, which collect fibres, together reduced microfibre emissions by 45 per cent (*PLoS One*, doi.org/hpnm).

While these products can reduce microfibre pollution in the short term, tumble dryer manufacturers need to design better filtration systems, says Lant. **Chen Ly**

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Really brief

SVIATLANA BARCHAN/ALAMY

How dogs pull human-like faces

The muscles around a dog's eyes and mouth contain a higher proportion of "fast-twitch" fibres than is seen in the facial muscles of wolves. This lets the dogs pull human-like faces, according to research presented at the Experimental Biology 2022 meeting held in Pennsylvania last week.

Robot finds issues with cancer studies

Fewer than 1 in 3 breast cancer studies are reproducible, according to an analysis that used a robot to partly automate experiments. The finding might not mean results lack accuracy, but could suggest work should be reported more carefully (*Journal of the Royal Society Interface*, doi.org/hpkp).

Air pollution a killer in tropical cities

Air pollution led to an extra 24,000 people dying prematurely in Dhaka, Bangladesh, between 2005 and 2018, an analysis suggests. The problem may worsen as such cities in the tropics grow, say the researchers behind the study (*Science Advances*, DOI: 10.1126/sciadv.abm4435).

Palaeontology

Triceratops was stabbed in the head

TRICERATOPS dinosaurs probably did fight each other using their horns, according to fossilised bones with evidence of puncture wounds sustained during life.

Triceratops lived just before all non-bird dinosaurs were wiped out 66 million years ago. It had a bony neck frill and three horns on its face: one on the snout and one over each eye.

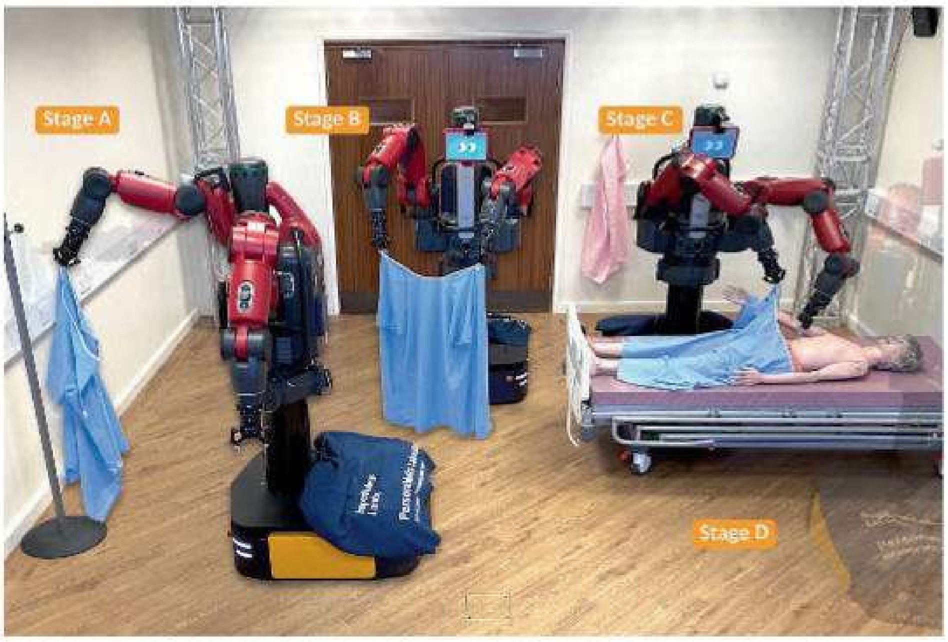
Several studies have suggested that triceratops fought using its horns, perhaps by locking them together and wrestling. This was based on triceratops fossils that showed large-scale damage, as if from impacts.

Ruggero D'Anastasio of the D'Annunzio University of Chieti-Pescara in Italy and his colleagues have examined a *Triceratops horridus* specimen nicknamed Big John, which was discovered in 2014 and was sold last year to a private collector.

There is a large hole in the right side of Big John's neck frill. D'Anastasio's team found evidence of newly formed bone around the edges of the hole, as well as signs of inflammation. This suggests Big John experienced the injury while still alive, and that the wound partially healed before the animal's death (*Scientific Reports*, doi.org/hpr9).

What caused the injury? "The shape and size of the lesion coincides perfectly with those of a triceratops horn similar in size to Big John," says D'Anastasio. This implies that Big John fought another triceratops, and during the battle it punctured Big John's neck frill with its horn.
Michael Marshall

Robotics



ZHANG ET AL. (2022)

Robotic nurse can dress a mannequin in a gown

A TWO-ARMED robot can dress a medical mannequin lying on a bed in a medical gown. The technology isn't yet ready for use on people, but it is an experimental step towards artificial nurses in hospitals.

Fan Zhang and Yiannis Demiris at Imperial College London tested their robot (pictured) in a scenario that mimicked the Certified Nursing Assistant test used in US healthcare, in which a trainee nurse has to put an open-backed robe on a person with weak or paralysed arms.

Flexible objects like a gown are difficult for robots to work with, as their shape and size vary depending on how they are draped. Instead of trying to track the entire gown, the robot focuses only on the key points it needs to grasp and manipulate.

The pair partially trained the robot's artificial intelligence control system using a computer simulation of the problem before running any physical trials. Once trained, the robot dressed the simulated patient 90.5 per cent of the time (*Science Robotics*, doi.org/hpnp).

"I don't think we can say robotic nurses are near," says Mehmet Dogar at the University of Leeds, UK, "but these are all research questions that we need to ask and investigate so that we can move towards that." **Matthew Sparkes**

Fertility

Rat pups born from lab-grown sperm

RAT sperm cells generated from stem cells in the lab have been used to produce fertile offspring for the first time. The approach could inform the artificial production of human sperm to treat infertility.

Until now, cells that give rise to sperm and egg cells, called germ cells, have only been produced in the lab in mice.

Toshihiro Kobayashi at the University of Tokyo and his colleagues extracted stem cells from rat embryos and grew them in the lab to produce germ cells that form sperm when implanted into rat testes. They then collected the sperm cells and injected them into egg cells, before implanting the embryos into female rats. These grew into healthy adult rats that were able to have offspring of their own (*Science*, doi.org/hpr5).

Next, the team hopes to uncover the common principles in sperm generation that are shared across rats and mice, which could inform the development of similar techniques in other mammals, like humans, says Kobayashi. Such research could then be used to gain insight into how human germ cells develop and what goes wrong to cause infertility, he says.
Carissa Wong

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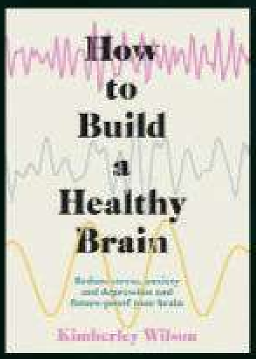

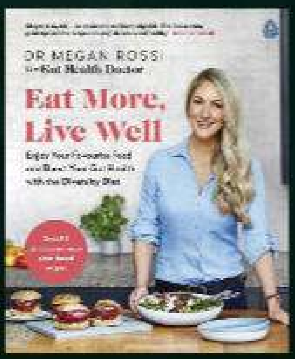

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TALK ONE

EAT MORE, LIVE WELL: ENJOY YOUR FAVOURITE FOODS AND BOOST YOUR GUT HEALTH WITH THE DIVERSITY DIET

Megan Rossi, dietitian, nutritionist and founder of the Gut Health Doctor

Gut health expert Dr Megan Rossi brings you her guide to understanding plant-based eating. Her science-backed approach to healthy eating is all about enjoying delicious food that you, your family and your gut bacteria will love, free from restrictions and fad-diets. It's called The Diversity Diet.

This way of eating is not about going vegan (unless you want to), cutting out food groups, counting calories, controlling your portions or only eating "diet food". Rather, it's about tapping into the latest scientific evidence about how our bodies and gut microbes work best. This means enjoying easy, flavoursome meals that will help you feel fuller for longer, reduced your risk of disease, help you live more sustainably and enjoy food that makes you and your gut happy.

TALK TWO

FOOD, MOOD, BRAIN & BEHAVIOUR: THE EVIDENCE LINKING FOOD AND NUTRIENTS TO BRAIN, BEHAVIOUR, MOOD AND MENTAL HEALTH

Kimberley Wilson, chartered psychologist, author and a governor of the Tavistock & Portman NHS Mental Health Trust

Pregnant women who consume higher levels of essential fats have children with bigger brains than those who do not. Improving nutrition in prison reduces violence by 30 per cent. Just a week on a Western-style diet leads to impairments in areas of the brain important to learning and memory. Those are just a few of the facts emerging from the scientific literature illustrating one of the most mundane, yet profound, influences on mental health and human behaviour: food.

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Comment

Mysterious beasts

Despite two centuries of incredible discoveries, there are some things we will never know about dinosaurs, says **David Hone**

MICHELLE D'URBANO

THE study of dinosaurs has made some amazing strides in the past 20 years. The discovery of numerous fully feathered dinosaurs offers incontrovertible evidence of the evolution of birds from their non-flying ancestors, for instance. We also have fossils that preserve ancient patterns of these long-extinct animals.

Around 50 new dinosaur species have been named every year of the past two decades. New studies have appeared on dinosaur behaviour, ecology, sex, physiology, brain structure, hearing and many more features besides. It is truly a treasure trove of data, and new avenues of research keep producing ever more interesting and surprising insights into these animals. And yet, rather inevitably, the fossil record is incredibly incomplete. For all the progress that has been made in two centuries of studying dinosaurs, there are still innumerable things that we don't know about them.

We may have some ideas about the colours of a few dinosaurs, but these are only a handful of individuals that may not even be that representative of their species, let alone any others. We have done detailed studies of how *Tyrannosaurus rex* could stand, walk, run and turn, but there is nothing like this even for the other 30 species of tyrannosaurs, let alone other groups. Those gaps may at least be filled with new finds one day, but what about the things we might never know?

Think about some of the strangest animals out there, those that are most unlike their near relatives or are hold-outs of some long-lost group. Giant tortoises, marine iguanas and flightless cormorants on the Galapagos Islands; kiwis, kakapo and tuatara in New Zealand; the (now sadly extinct) rails of Hawaii; lemurs and extinct elephant birds on Madagascar; and so on.

What they have in common is where they live – islands, usually ones that are both volcanic and a long way from any other land masses, and they are often tropical too. These are places where isolated populations can cling on and take interesting turns, as small groups evolve under unusual conditions. They are often free from some of the constraints that come from the presence of competitors and predators, which can allow them to flourish where elsewhere they have perished, or to diversify and produce new and unusual forms.

The thing is, though, such environments are terrible for forming fossils. Small bits of land are likely to have limited numbers of large rivers and lakes with lots of silt to bury animals. Tropical environments have very high rates of decay, so dead bodies often don't last long enough to be buried. Volcanic islands can easily sink into the sea and be at the mercy of tectonic activities, and such places are generally very unlikely to be exposed on the surface where palaeontologists can pick at them 100 million years later.

In short, however bizarre we consider dinosaurs to be now, they almost certainly produced far more interesting and unusual animals on all manner of islands in the Mesozoic Era (around 252 million to 66 million years ago), but it is incredibly unlikely that we will ever find them. Either the fossils never formed or those islands have been destroyed and are now inaccessible.

Our knowledge of the evolution of animals on islands is enough to give us confidence that strange dinosaurs appeared in these places, though similarly, our understanding of the processes of fossilisation tells us that we are unlikely to access the fossils in the future, however much we dig.

We have learned so much about dinosaurs, and there is still so much more to come. But there are fascinating gaps we might never fill, with only tantalising hints about these wondrous ancient creatures. ▮

David Hone is the author of *The Future of Dinosaurs* (Hodder & Stoughton)

Field notes from space-time

Taking on the invisible universe

Dark matter is now my focus, but the difficult problems of dark energy and cosmic acceleration are still on my mind, writes **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an assistant professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her research in theoretical physics focuses on cosmology, neutron stars and particles beyond the standard model

PART of what makes my intellectual life interesting is that I do research not only in physics and astronomy, but also in social studies of science. On the social studies side, I'm particularly interested in how race and gender shape how physics happens, and while thinking about this, I often run into the question of language: how does it influence the ways that people from different communities relate to science? Believe it or not, this is what first came to mind when a reader wrote in to ask why I work on dark matter instead of dark energy.

Scientifically, it is a fair question, but I wondered whether the juxtaposition only existed in the reader's mind because both contain the word "dark". In some ways, that is pretty much the only thing they have in common: the use of the word "dark" to say "we as scientists can't see it and don't know what's going on".

As a quick reminder, cosmologists now believe that about 95 per cent of the energy-matter content in the universe is comprised of dark energy and dark matter. Dark energy is a term that describes a probable answer to an open question in observational cosmology: why is the expansion of the universe accelerating? Yes, for whatever reason, space-time is not only expanding, but that expansion is picking up speed. It is completely wild! So far, our simplest explanation is that there is an energy associated with empty space that is causing this expansion to go faster. This has come to be known as dark energy.

Meanwhile, dark matter behaves very differently to dark energy: it gravitates exactly the way we expect matter to gravitate. But, like dark energy, we haven't ever seen it or interacted with it. We know it has to be a different type of particle to all of the ones we have seen in the lab, and right now we are trying to figure out exactly what it is.

The social studies side of my brain is interested in the way these names work, the way that scientists first clung to the name dark matter and then evidently adapted that when the cosmic acceleration problem came along. This curiosity maybe runs in parallel with that of the person who asked me why I spend so much time on one and not the other. Like I said, it is a good scientific question.

> **"For whatever reason, space-time is not only expanding, but that expansion is picking up speed. It is completely wild!"**

I'm not sure I have a good scientific answer. I do have a personal one, though. I came of age with the cosmic acceleration problem. As a teen, I cut out a figure from a *Scientific American* article about the new discovery that space-time's expansion is accelerating, and I glued it to my application to the California Institute of Technology. I wrote underneath: "I want to solve this problem." Throughout the next 11 years or so, that is exactly what I tried to do. In my first year as a PhD student, I stayed up late at night, under the impression that if I just read enough papers and thought hard enough, the solution would come to me.

I eventually graduated with my PhD, having defended "Cosmic acceleration as quantum gravity phenomenology" as my dissertation. I believed – and still do – that cosmic acceleration is our first experimental hint at how to solve the great quantum gravity problem, the question of how to merge quantum mechanics with gravitation. This perspective is still not particularly fashionable, but here I am, clinging to it.

This is probably also why I came to see dark energy as a kind of intractable problem for me to personally work towards solving. On the one hand, I have a gut feeling (that could be wrong) about how it fits in with other questions we have. On the other, there are physicists who believe that the rest of us are overthinking it. In their view, it is just a constant energy known as the cosmological constant, and the value of the cosmological constant is an accident.

This sets us up for a philosophical confrontation that I find to be very distressing. If the cosmological constant had another value, the universe would have evolved differently, and we might not be here. Variations on this theme are often known as the anthropic principle. I hate it, because that doesn't feel like an explanation so much as resignation.

Eventually, I stopped working on trying to solve the cosmic acceleration problem because I wasn't having any ideas that were better than fans of anthropics, and anthropics made me sad. In the meantime, I have developed an expertise in dark matter and my contribution has allowed me to draw from ideas in atomic physics that I always found fascinating.

Dark matter is a major open cosmological question and, at least for the moment, it is more fun to work on. It is also possible that my subconscious is working away at a good explanation for dark energy – so maybe when it is done, I'll be back. ▮

Chanda's week

What I'm reading

This month, I am very into Aria Halliday's Buy Black: How Black women transformed US pop culture.

What I'm watching

Like many people here in the US, I am completely in love with both Abbott Elementary *and the US version of* Ghosts.

What I'm working on

I'm giving a TED talk on dark matter, and preparing is a lot of work!

This column appears monthly. Up next week: Graham Lawton

PML | Plymouth Marine Laboratory

www.pml.ac.uk

Digital science roles to transform marine science

Could you be part of an ambitious team seeking to harness the full potential of AI, machine learning and autonomy in support of a sustainable ocean future? Plymouth Marine Laboratory (PML) is a world-leading marine research charity, committed to the pursuit of research excellence to support our vision of a healthy and sustainable ocean.

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Tasked with shaping and delivering PML's Digital Science Strategy you will provide lab-wide strategic leadership to facilitate digital transformation across all science areas, mentoring colleagues and enabling PML to fully embrace a Big Data future and capitalise on digital tools and techniques such as AI and Machine Learning.

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- Demonstrable understanding of the tools and infrastructure required for carrying out digital-centric research (coding; data formatting and manipulation)
- Experience in securing external funding to support research activities, training and capital infrastructure investment
- Ability to demonstrate the interoperability between the different datasets which form the PML data ecosystem and data ecosystems held elsewhere.

To discuss the role in more detail please contact Steve Widdicombe, swi@pml.ac.uk

Senior Scientists (x4) £40,486 - £46,410 pa

We are looking for biogeochemists, ecologists and social scientists with digital skills to help drive PML's digital strategy forward. Using digital technologies and advanced techniques to carry out and publish world-class marine environmental and social interdisciplinary research, you will inform some of the most significant global environmental challenges while helping to build knowledge across the organisation.

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- Ability to lead research collaboratively across specialisms, together with project and financial management experience
- A track record of securing research funding
- Experience of conducting social or natural science within an interdisciplinary setting.

To discuss the role in more detail please contact Steve Widdicombe, swi@pml.ac.uk

Data Systems Architect £32,527 - £38,486 pa

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Essential requirements:

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- Understanding of the purpose and value of datasets and how to determine the most suitable format of data to use for a given purpose or problem
- Understanding of the importance of data synthesis and able to implement the best methods for data integration
- Experience with digital twins, data visualisation and Artificial Intelligence desirable.

To discuss the role in more detail please contact Tim Smyth, tjsm@pml.ac.uk

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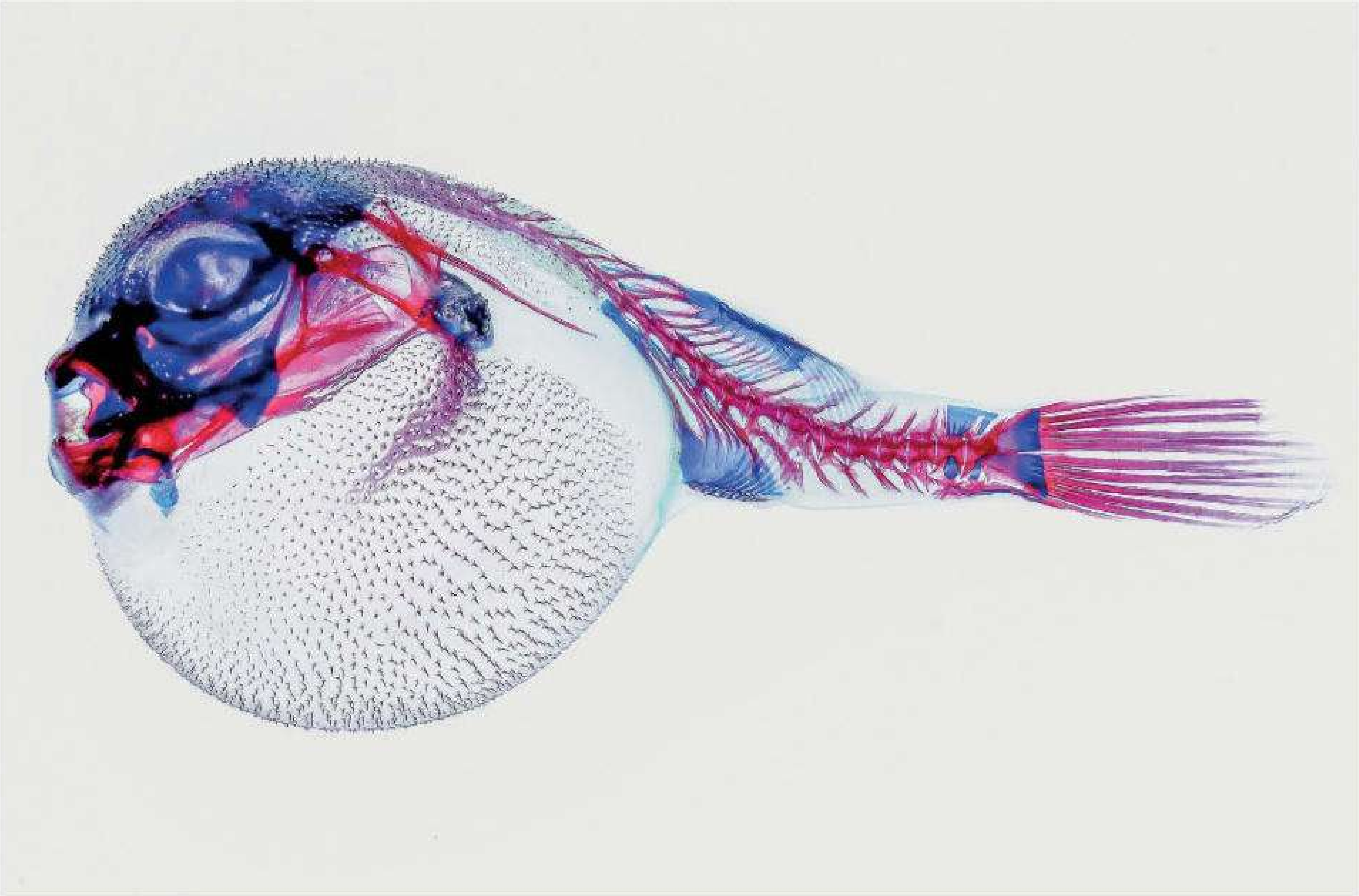
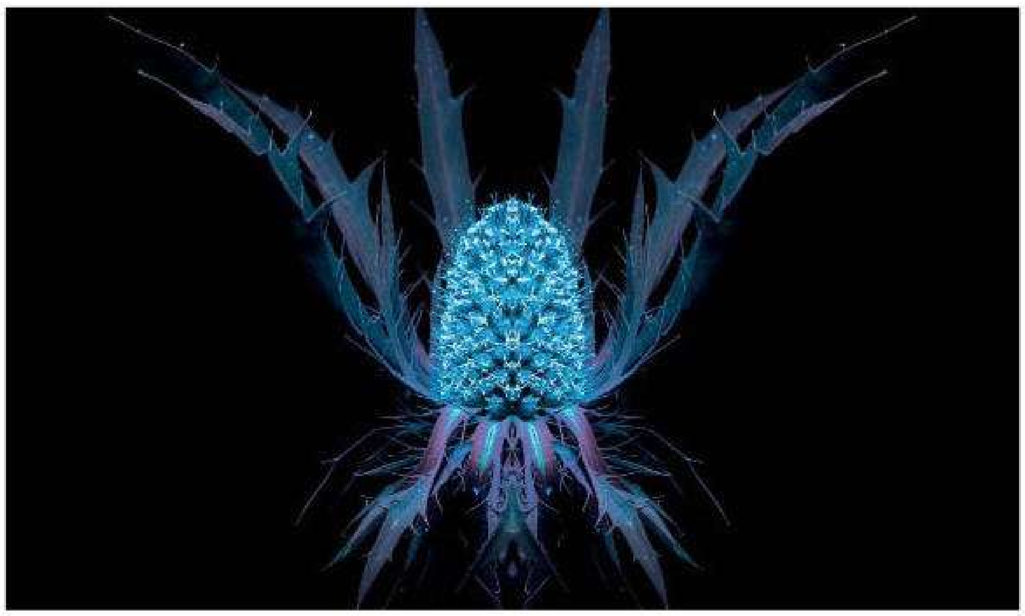


ARUN KUPPUSWAMY MOHANRAJ/PROFESSIONAL COMPETITION/WILDLIFE & NATURE

MANUEL ENRIQUE GONZÁLEZ CARMONA/PROFESSIONAL COMPETITION/LANDSCAPE

LORENZO POLI/PROFESSIONAL COMPETITION/LANDSCAPE

DEBORA LOMBARDI/PROFESSIONAL COMPETITION/WILDLIFE & NATURE



DEBORA LOMBARDI/PROFESSIONAL COMPETITION/WILDLIFE & NATURE

Winning shots

THESE incredible images are all winning or shortlisted entries in the professional competition of the 2022 Sony World Photography Awards, a global contest celebrating contemporary photography.

The top-left image of a pufferfish was taken by Arun Kuppuswamy Mohanraj as part of his project Diaphonization – Dyeing the Dead. Mohanraj dehydrated the pufferfish in ethanol to harden the bone and cartilage, before using coloured stains to make the bones appear red and the cartilage blue. Then he exposed it to the enzyme trypsin, which digested most of the tissues and made them transparent. The image was shortlisted in the Wildlife & Nature category.

In the bottom-left photo, Manuel Enrique González Carmona captured the colourful mineral deposits of a copper mine's toxic waste pond, located in Huelva, Spain. It was shortlisted in the Landscape category.

The two smallest photos were taken by Debora Lombardi and were shortlisted in the Wildlife & Nature category. Lombardi used a photography technique to show the fluorescence of flowers under UV light, revealing them as insects might see them.

Finally, Lorenzo Poli's image of a volcanic desert in the Icelandic Highlands celebrates what he calls the "untamed world" of Earth. Poli's Life on Earth series won in the Landscape category.

All of the winning and shortlisted images are on show at Somerset House in London until 2 May.

Gege Li

Editor's pick

Global catastrophes also threaten to destroy hope

26 March, p 28

From Denis Watkins, Truro, Cornwall, UK

Graham Lawton refers to the latest catastrophe we face – Russia's invasion of Ukraine – and the dire environmental and humanitarian consequences. There is another insidious and pervasive impact of crises, global warming chief among them. It is the emotional toll, the erosion of long-term expectations that were once taken for granted.

The assumptions that we could undertake years of study to achieve a qualification, confidently commit to decades of paying a mortgage to buy a house and raise a child in a stable environment have been severely shaken. A different mindset is developing and it is one beset by pessimism. Worst of all, there doesn't seem to be the leadership to provide a solution.

A site for UK nuclear waste? I pick London

5 March, p 19

From David Wheeler, Carlisle, Cumbria, UK

Further to your look at the rising cost of a proposed underground deposit for nuclear waste in the UK, the site remains undecided. Nuclear waste needs to be buried in a rock that is impermeable, flexible (so it won't form fissures through which material can leak), of reasonable depth and with good transport links. The London Clay would seem to be ideal.

Martin Rees gives us some very wise words

12 March, p 46

From David Seager, Edinburgh, UK

The interview with Astronomer Royal Martin Rees is a gem, sparkling with wisdom. While we are currently witnessing all too clearly the shortcomings of *Homo sapiens*, the idea he raises that our civilisation may be usurped quite soon by electronic entities, or other complex intelligence, is actually heartening.

Although there is an increasing awareness among some that a drastic reduction of the human population would spare Earth, Rees's vision gives us hope that the planet won't have to wait millions of years for a cataclysmic ice age or asteroid collision to achieve this.

Pandemic niceties may not last for that long

19 March, p 27

From Gillian Peall, Macclesfield, Cheshire, UK

I think we will be fighting a losing battle if we expect personal responsibility on coughing and sneezing in public to endure.

I recall a public health campaign in the UK about 75 years ago, when I was about 10. Through directives, humour, jingles and slogans, it aimed to stop people spreading infections – which cause lost time at work – and thus delaying their part in "economic reconstruction" after the second world war.

That message didn't lead to a long-lasting change in behaviour. It seems cultural transmission doesn't operate when it comes to respiratory tract infections.

Language was surely the bedrock of early humans

26 March, p 38

From David Marjot, Weybridge, Surrey, UK

Your look at the evolution of language reminded me how amazing it is that most infants start to speak so early and how quickly motor and intellectual development of speech outstrips all other skills. Speech must have been a very early development in the evolution of our species.

Stone Age peoples would have spoken 19 to the dozen. It is only our arrogance, ignorance and prejudices that lead us to assume they were primitive, and physically and intellectually stunted.

Yes to the joy of science, backed by the joy of art

26 March, p 46

From Mike Newman, Shrewsbury, Shropshire, UK

I loved your interview with Jim Al-Khalili. It brilliantly caught his infectious enthusiasm for science. I, too, love the joy of science, but as someone with a strong interest in the arts, I also celebrate this field's input in interpreting our world.

For example, if we drill down to the quantum level, much of our world is simply too confusing to "get our head round", so we use metaphors and stories that make it workable day-to-day.

A world without rabbits would be just fine by me

19 March, p 43

From Tony Power, Sydney, Australia

I disagree with Graham Lawton, rabbits should be eradicated. If places outside Australia and New Zealand want to have limited populations of these pests, that would be their choice.

Another reason not to go down nuclear power road?

19 March, p 7

From Christopher Jessop, Marloes, Pembrokeshire, UK

For proponents of nuclear power, Russia's shelling of nuclear sites in Ukraine has shown that no reactor can be safe. You can't design against military ignorance: attacking reactors, severing grid connections, threatening all with severe contamination worse than that of the Chernobyl disaster.

If hit by hypersonic missiles that can outrun defence systems and breach all containment, any working reactor or waste facility instantly becomes a dirty bomb.

True AI can only succeed if we capture life's mystery

19 February, p 38

From Arun Kashyap, Washington DC, US

"Making a mind" asks whether psychology or neuroscience is best for making artificial intelligence that thinks like us. The quest, I believe, lies more in translating into AI the mystery of life's purpose and how we interact with all living things – not "merely" copying the brain's complexity.

Does a mountain view really lead to generosity?

5 March, p 44

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

Jess Craig tells us that people exposed to awe-inducing stimuli, such as sweeping panoramic videos of mountains, were more likely to act more generously.

Does this mean that peoples who permanently inhabit such vistas, such as the Swiss, can be distinguished from the rest of us by their inherent generosity?

Deep freeze will dispatch your slugs and snails

5 March, p 48

From Erin Moore, Bellingham, Washington, US

After amassing slugs and snails using Rory Mc Donnell's bread-ball bait, the question arises of "termination". I use a method I learned decades ago from a gentle but determined gardener. Collect your molluscs into a bag, seal it and place in the freezer where they naturally "go to sleep". ▮

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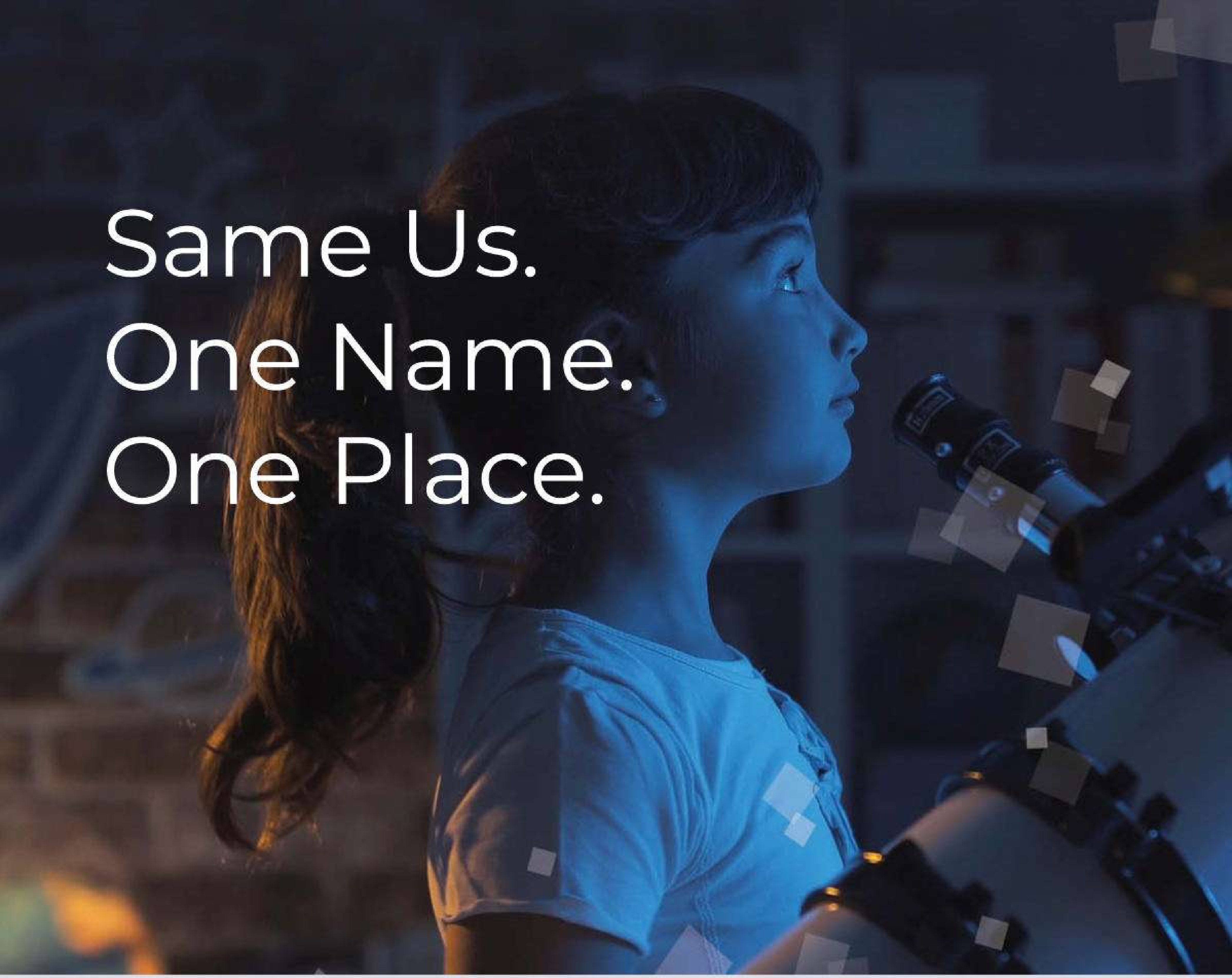
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Romancing the science

Is studying love still regarded as a lightweight option? A moving story of two neuroscientists who fall in love makes a strong case against that, says **Elle Hunt**

Book

Wired for Love: A neuroscientist's journey through romance, loss and the essence of human connection

Stephanie Cacioppo

Robinson

SHE studied love, he researched loneliness – it was such a perfect match it could have been made in a lab. When Stephanie Ortigue met John T. Cacioppo at a neuroscience conference in Shanghai, both knew their whirlwind romance would be influenced by their research and inform it in turn.

It was 2011. Stephanie was 36, and publishing papers on pair-bonding and romantic love, despite having never known it herself. "I assumed I would never experience romance outside the laboratory," she writes. John was an expert on the dangers of loneliness to physical and mental well-being, and, at 60, was twice divorced, "not lonely, but by myself", he said.

Both were self-avowed workaholics until they found love, and almost at first sight. "And once I did, my life and my research were changed forever," writes Stephanie (who took her husband's name). Now, in *Wired for Love*, Cacioppo moves away from case studies and turns her scientific attention onto her marriage. Her book is "both the story of my science, and the science behind my story".

As a tale of romance, it is epic, culminating in a spur-of-the-moment wedding in the Luxembourg Garden in Paris and a profile in the popular Modern Love column in *The New York Times*. But what takes the Cacioppos' story beyond a heart-warming reminder to never lose hope are their professional insights into our brains in love.

Through their courtship and marriage, Stephanie and John studied themselves, observing and noting "the intention, the subtext underlying every step we took as a fledgling couple" and its effect on cognitive functioning.

In *Wired for Love*, Cacioppo explores their findings with critical distance. What was behind their instant attraction? How could they feel so close when they were often oceans apart? Would they have fallen in love if they hadn't found each other physically attractive? What part did their expectations play? And for two people who thought themselves in love with their work, how did the real thing compare?

Cacioppo, a psychiatrist and behavioural neuroscientist at the University of Chicago, enlarges her experience with studies (her own, and others) for the sake of non-scientific readers who may be seeking to understand and perhaps cultivate romantic connection themselves. The appetite for these scientific insights into our personal lives is evident in popular non-fiction such the recent *Heartbreak: A personal and scientific journey* by journalist Florence Williams. And it is even shown by the bashful requests by Cacioppo's students to use her "love machine", a patented computer test that aims to reveal their unconscious preferences of partner from their brain activity.

"It speaks to the snobbery and sexism in what is decided worthy of study"

Yet Cacioppo – who became the first female president of the Society for Social Neuroscience – describes struggling to be taken seriously early in her research of romantic love, with most neuroscientists devoting themselves to the darker side of the emotional spectrum.

In the early 2000s, a male faculty adviser told her that to study love would be "career suicide", that the subject was too lightweight to be the basis for academic research. She was first able to overcome that bias by substituting the word "love", in a grant proposal, for "pair-bonding".

And by studying the brain in love, we can see it as a complex and hardwired neurobiological phenomenon, suggesting to Cacioppo that "love is not merely a feeling but also a way of thinking".

Her early career experience speaks to the snobbery and sexism at play in what is deemed worthy of study, as well as how much we don't know about what might be considered a universal experience and an essential need.

As covid-19 laid bare, writes Cacioppo, "the need for love might be less immediate than the need to avoid danger, but it is by no means a luxury". Indeed, John's death from cancer in 2018 shows love's potential to both devastate and endure. Cacioppo confronts her loss boldly, concluding that "love is a much more expansive concept than we give it credit for", not all of which can, or should, be explained by chemistry. ■

Stephanie Ortigue and John T. Cacioppo tracked their burgeoning love

JOE STERBENC/UNIVERSITY OF CHICAGO

Elle Hunt is a freelance writer based in Norfolk, UK

Truth and lies

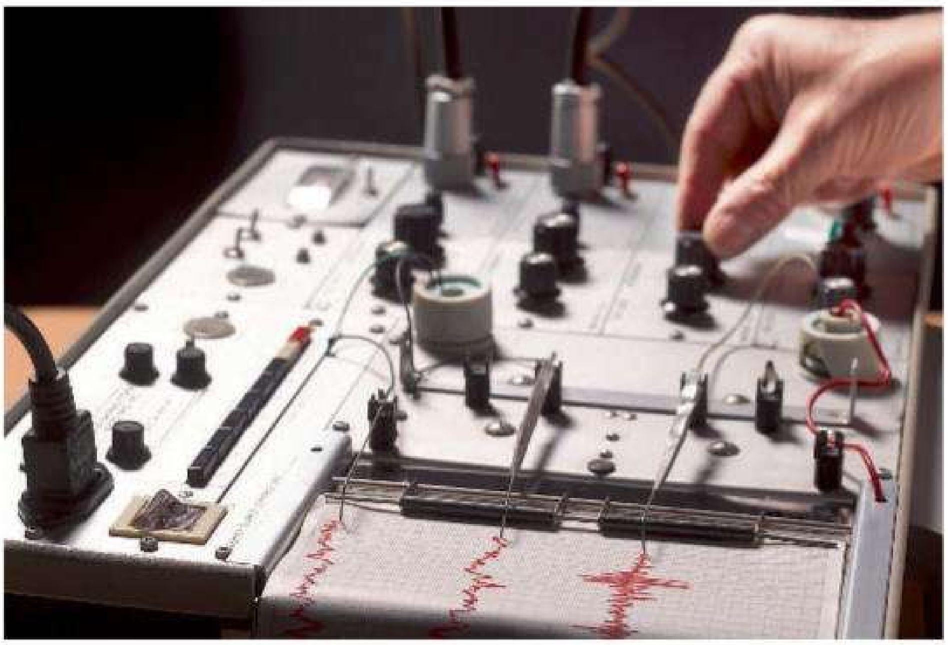
The intriguing origin story behind the polygraph test should make us worry about extending its use, says **Chris Stokel-Walker**

Book

Tremors in the Blood

Amit Katwala

Mudlark



PETER DAZELEY/GETTY IMAGES

The polygraph test looked scientific because it was based on physiological readings

THE polygraph test has been used in criminal prosecutions for decades – a silver bullet for police and prosecutors alike. Measuring heart rate, breathing speed and the conductivity of skin, it is supposedly infallible and given the respectable veneer of science in a courtroom. Someone who flunks the test must be lying, their body's tell-tale signs betraying their deepest secrets.

Yet that is far from reality. "There is no single tell-tale sign of deception that holds true for everyone – no Pinocchio's nose," writes Amit Katwala in *Tremors in the Blood*. A misfiring test has real ramifications: the US-based National Registry of Exonerations holds records of more than 200 people who failed a polygraph test, were convicted of a crime and imprisoned, but were later found to be innocent.

Katwala's book traces the test's history, looking at the early adopters of the technology and some of its earliest cases. The book goes back a century, telling the story of John Larson and Leonarde Keeler, co-inventors of the polygraph (called the emotograph by Keeler), and August Vollmer – all three key to its adoption by US police forces and later worldwide.

Larson was a complex character, breathed back to life by Katwala's meticulous research. A bookish, morally driven individual, Larson joined the Californian police force in the early 1920s. Unlike the high school dropouts and extortionists who filled the force's ranks then, Larson was the only police officer in the US with a PhD, in physiology. He would work in university labs by day and police the streets at night.

Larson's master's thesis had been on the relatively new technology of fingerprint identification, which had recently become admissible in court. He thought there were still more ways of catching criminals. He was lucky to work under a police chief, Vollmer, who was more bookish than he liked to let on.

Vollmer was equally driven to do the right thing, and was constantly trying to improve policing. In 1921, after reading an academic paper by a psychologist and lawyer who had tested whether his friends were lying based on their blood pressure readings, Vollmer asked Larson to develop a machine that could do the same. The result was mocked by fellow officers, and described in newspapers as looking like a combination of radio, gas stove, stethoscope, dentist's drill, barometer, wind gauge, time ball (an old form of clock) and watch – but it appeared to work.

Katwala vividly portrays those heady early days when the polygraph seemed to catch out liars. Then, he deftly delivers the twist in the tale: 40-odd years after cobbling together the first machine, Larson forswore his invention because of the way it was used. It was "nothing more than a psychological third degree aimed at extorting confessions, as the old physical beatings were", he said in an interview – far removed from his meticulous scientific approach.

The book captures the wonder of scientific breakthrough – and what happens as the story becomes more complex. In 1965, the year Larson died, the US House Committee on Government Operations warned that the world had been hoodwinked by "a myth that a metal box in the hands of an investigator can detect truth or falsehood".

Yet the polygraph is still being used. In 2021, the UK began polygraph testing people convicted of terrorism offences and, later that year, convicted domestic abusers, despite the fact there are serious doubts about whether it works.

Why has the polygraph remained on its pedestal? Perhaps because no one, until now, has placed it, warts and all, in its historical and scientific context. ▮

Chris Stokel-Walker is a journalist based in Newcastle, UK

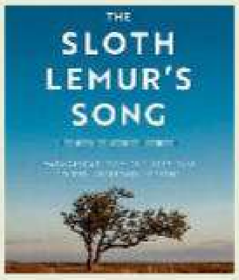
Don't miss

Visit

Don't Adjust Your Mindset by artist Pete McKee welcomes you to a futuristic Great(ish) Britain of lockdown, climate change and digital dependence. Running from 22 April at London's Hoxton Arches.

Watch

Russian Doll returns to Netflix on 20 April for a second season. The highly successful series stars co-creator Natasha Lyonne as Nadia, a woman facing an unusual existential crisis: she is trapped in a time loop on a subway train in Manhattan.



Read

The Sloth Lemur's Song haunts Alison Richards's account, fuelled by more than 50 years of research, of Madagascar's deep past and uncertain present. This island microcosm is a bellwether for the whole planet.

MIDDLE: NETFLIX

The film column

Stan's secret mission

The intelligent, moving *Apollo 10½* is an animation about the fantasy world of a child obsessed with the space race. It took 18 years to make, and ended up owing as much to a movie pioneer as to high tech, says **Simon Ings**

Simon Ings is a novelist and science writer. Follow him on Instagram @simon_ings

Film
Apollo 10½: A space age childhood
Richard Linklater
Netflix

Simon also recommends...

Film
Gulliver's Travels (1939)
Max Fleischer
A rotoscoped Lemuel Gulliver defends the miniature kingdom of Lilliput in an animated masterpiece to rival Disney.

Book
No Requiem for the Space Age
Matthew Tribbe
Oxford University Press
Matthew Tribbe sets aside fond reminiscences of the Apollo years and reveals the issues that dogged the project from its inception.

NETFLIX

Stan (Milo Coy) creates a fantasy where he beats the adults into space

WHAT we really seek in space is "not knowledge, but wonder, beauty, romance, novelty – and above all, adventure", sci-fi writer Arthur C. Clarke told the American Aeronautical Society in 1967, as the gloss was beginning to flake off the Apollo project.

By the time Apollo 11 launched on 16 July 1969, NASA's bid to land astronauts on the moon (the most expensive civilian undertaking in history) couldn't help but be overshadowed by the even more costly Vietnam war.

Only a little of this trickles into the consciousness of 10-year-old Stan (newcomer Milo Coy) as he propels himself on his Schwinn bike around Houston, North America's own "Space City". His father is one of the 400,000 small cogs who contributed to the space programme – but this is enough to inspire a whole other reality in Stan's head, in which he is hired for a secret Apollo test flight before the grown-ups blast off to glory.

Jack Black (whose engineer mother worked on Apollo 13's life-saving abort-guidance system) plays Stan as an adult. He is a narrator whose perspectives have widened to take in the politics of the time, but not in a way that undercuts the story.

Directed by Richard Linklater, *Apollo 10½: A space age childhood* is, in the best sense, an innocent film, an animation about wonder, beauty and adventure. It isn't so much a nostalgic movie as one about childhood's possibilities and fantasies.

> **"*Apollo 10½*, which its director noodled over for 18 years, has taken longer than the space race"**

The film uses interpolated rotoscoping, a method developed by art director Bob Sabiston for another Linklater film, *Waking Life*, in 2001. Sabiston's Rotoshop software let artists draw over QuickTime files, much as Max Fleischer drew over movie stills to pioneer rotoscoped animation in the 1910s.

When you rotoscope using software, you can trace every frame, or space out your tracing and let the computer fill in the missing frames – a process called interpolation. This creates an interesting effect because the computer doesn't understand the physical structure of the objects you are rotoscoping, and tries to find the most direct path to morph one shape into another.

Rotoshop worked a treat for the surreal meanderings of *Waking Life*, but keeled over somewhat in 2006 when a frantic studio expected it to speed up production of Linklater's adaptation of the Philip K. Dick classic, *A Scanner Darkly*. It couldn't and it didn't.

Sixteen years on, *Apollo 10½* realises Sabiston's original 2½D conception. But that is only partly down to better tech. In fact, Linklater used traditional rotoscoping. The two-year hiatus caused by covid-19 gave him and his team the time they needed.

Time is rarely on the side of the film-maker, but Linklater has chiselled out a unique relationship with the stuff, particularly with *Boyhood*, filmed from 2002 to 2013 with the same cast. *Apollo 10½*, which Linklater noodled over for 18 years, has taken longer than the space race.

Most studios would struggle with such timescales, so it is no surprise to find *Apollo 10½* streaming on Netflix. Its 222 million subscribers already sit at their screens, waiting to be entertained. Relieved of the need to recoup single, heavy investments over relatively few weekends, Netflix can work constructively with its artists. On the evidence of *Apollo 10½* alone, it looks like we can bury fears that streaming will kill the feature film. ▮

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The never-ending infinity story

Mathematicians might have finally made a breakthrough on a problem that has been baffling them for 150 years, says **Timothy Revell**

INFINITY is a concept that is easy to think about, but hard to understand. Who hasn't looked up at the night sky and wondered whether space goes on forever? Is it an endless expanse, or does it eventually just stop? What does it mean if it doesn't?

For trained mathematical brains, the infinite is if anything even more bamboozling. Mathematicians have known for well over a century now that infinity isn't just one thing, it is infinitely many. There is an unending tower of ever greater infinities stretching up all the way to... well, whatever you'd like to call it.

That isn't even the worst of it. Although the existence of this tower of infinities is a logical consequence of mathematics as we know it, that same mathematics is powerless to describe it completely. Chip away at the plaster to reveal the structure underneath and you see that crucial load-bearing beams are missing in the lower levels, suggesting that the foundations of mathematics itself are unstable.

Mathematicians have long argued about how best to shore the infinite tower up. Some say we should simply leave well alone and hope for the best. Others have proposed fixes, variously deemed too costly, unlikely to work or not in keeping with the original style. No one has yet made anything like a breakthrough. Except, perhaps, until now. After decades of apparent stalemate, serious progress seems to have been made on the baffling question that lies at the heart of it all: a nearly 150-year-old unproven conjecture known as the continuum hypothesis.

Humans have probably been thinking about the unending for most of our existence. "Infinity is a very natural concept," says Vera Fischer at the University of Vienna in Austria. Jain mathematicians in India in the 4th and 3rd centuries BC believed that infinities come in more than one size, but it wasn't until the 19th century that mathematician Georg Cantor really started to grasp infinity's true, slippery nature.

To get a handle on his thought process, imagine drawing a number line. The first numbers you might add to it would be the natural numbers – the counting numbers that go 1, 2, 3 and so on. Although mathematically imprecise, the "and so on" means you could continue the counting process forever. You will never run out of natural numbers; their number is infinite.

That is where the weirdness starts, however. Now think of the even numbers: 2, 4, 6 and so on. Intuitively, you would say there are fewer even numbers than there are natural numbers – half as many, perhaps. But that "and so on" makes plain that there is no end point to them, either. In fact, you can pair up every natural number with an even number and vice versa – (1,2), (2, 4), (3, 6) and so on – so there must be the same "amount" of each. These two infinite sets of numbers have the same size. This size is written $\aleph_0$ (pronounced aleph-null) and these sets are said to be "countably" infinite.

There are lots of countable sets of numbers. The integers, for example, which comprise the natural numbers, zero and all the negative

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“Infinity’s wobbling tower suggests the foundations of mathematics are unstable”

natural numbers, are also countable. Perhaps more surprisingly, so are the fractions. There are clearly a lot of fractions, but Cantor used a cunning trick to prove that you can still perfectly pair them up with the natural numbers: they, too, are countably infinite (see “A rational pairing”, page 40).

Into the uncountable

That doesn’t exhaust all the numbers you might think to string along your number line, however. Numbers like π and √2 can’t be written as fractions, and when written in decimal continue forever after the decimal point without a repeating pattern. Add in these irrational numbers to the set of all numbers already discussed, and you have what is called the set of real numbers, or the continuum.

Cantor wondered whether, like the fractions, the real numbers were countably infinite too, but it turns out they aren’t. However you pair the real numbers with the countable numbers, there will always be real numbers that you have missed (see “Accountably uncountable”, page 42). “Cantor discovered that there are a lot more real numbers than natural numbers,” says Ralf Schindler at the University of Münster in Germany. Cantor had discovered that infinity comes in different sizes. The countable infinity was the smallest one, but there was also a “continuum” infinity larger than it.

That wasn’t the half of it. If you take any set of numbers, there is another set that contains every possible combination of the elements in the original one. Cantor discovered that this “power set” of an infinite set was infinitely large, of a larger size. Because you can repeat this process, taking the power set of a power set *ad infinitum*, he had found a method to produce an infinite ladder of infinities.

This shocker just raised more questions. “Once you discover such a thing, you want to draw a map of the different kinds of infinity,” says Schindler. Cantor knew that the countable sets were the smallest infinity, but was the continuum infinity the next level up? This infinity is known as $\aleph_1$, or aleph-one, and Cantor believed that it and the continuum infinity were one and the same. This assertion became known as the continuum hypothesis, but Cantor was never able to prove it.

Neither was anyone else. This all happened around 1878, and 22 years later, in 1900, mathematician David Hilbert put proving or disproving the continuum hypothesis top of ›

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his hit list of 23 problems for mathematicians to solve in the 20th century. Now, 22 years into the 21st century, it remains unsolved.

Granted, in the mid-20th century, an almighty spanner was thrown into the works. When Hilbert wrote his list, mathematicians believed that a logical conjecture, if built up rigorously on solid, agreed axioms of logic, could either be true or false. That changed in 1931 when Kurt Gödel produced his infamous incompleteness theorems. These showed that there was a third option: rather than being true or false, a conjecture could be "undecidable". Even if you started with the right assumptions, in the form of logical axioms, and worked painstakingly through what they implied, there were some things you could never prove one way or the other.

In 1940, Gödel provided the first evidence that the continuum hypothesis might just be such a beast. He took the first step himself by proving that mathematics as it stood wasn't strong enough to disprove the hypothesis: it couldn't say definitively that the continuum wasn't size $\aleph_1$. In 1963, mathematician Paul Cohen landed what seemed like a final blow, showing that mathematics wasn't strong enough to prove that they were the same size either. The continuum hypothesis was neither true nor false.

End of story? Not a bit of it. The inability of mathematics to say anything sensible about what, all things considered, seemed to be a relatively simple piece of mathematics was enough to convince many people that mathematics itself was the problem. After all, says Schindler, if infinity exists outside mathematics, then the continuum hypothesis must be decidable one way or another, even if we can't figure it out yet. Some dispute that premise (see "Is infinity real?", right), but this doesn't mean that strengthening the logical foundations of mathematics wouldn't make an answer to the continuum hypothesis possible.

Most mathematicians work far enough away from the foundations that they don't worry too much about what is going on underground. But dig a little and you find a collection of logical axioms underpinning set theory known as ZFC (for "Zermelo-Fraenkel, plus the axiom of choice"). These contain very basic assumptions about mathematical sets, such as the axiom that two sets are of equal size if they contain the same elements.

"You can essentially construct everything in mathematics using sets, and ZFC is powerful enough that you can do most things that

A RATIONAL PAIRING

The countable numbers (1, 2, 3 and so on) and the rational numbers (anything that can be written as a fraction) are clearly both infinite sets, but are they the same size? Because every countable number is also a rational number (1, 2, 3… is the same as 1/1, 2/1, 3/1…), the countables must be either smaller than the rationals or equal in size to them.

When he was exploring infinities in the 19th century, Georg Cantor worked out a clever method for proving that the opposite is also true: the rationals are either smaller than or equal in size to the countables. As both of these statements are true, this must mean the two sets are actually the same size.

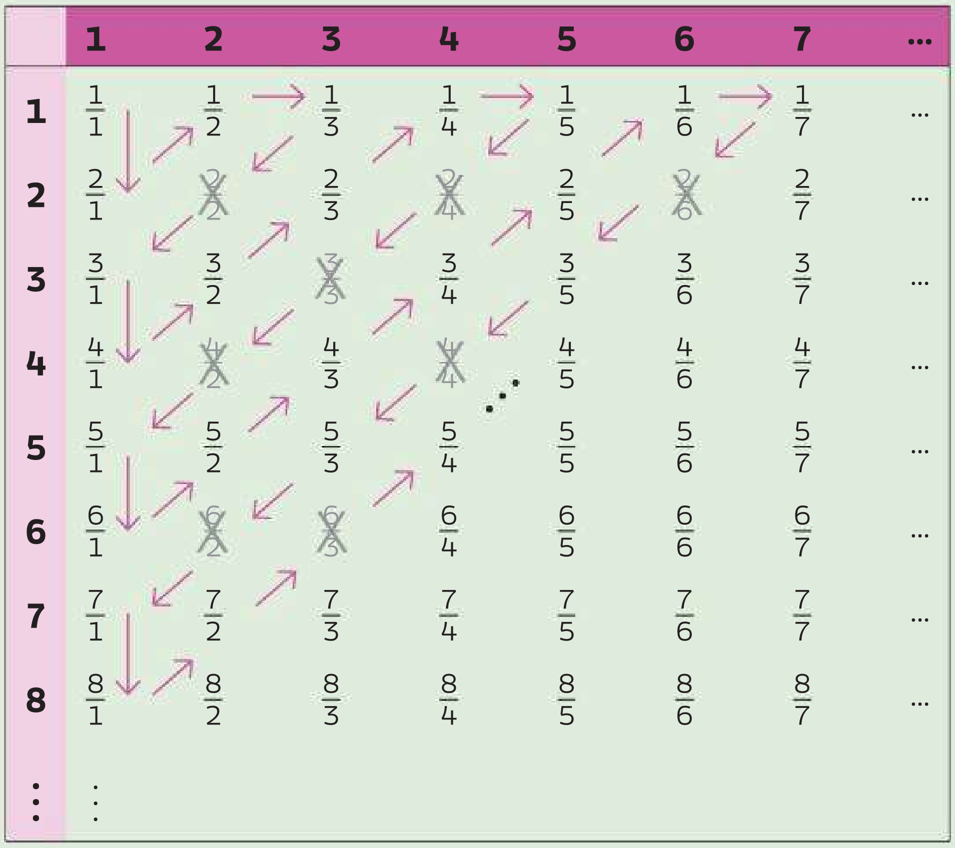
To understand Cantor's trick, first imagine putting together a grid consisting of fractions where the numerator (the number at the top of a fraction) is given by the number in the top row and the denominator (the bottom part) by the number in the left column (pictured, below).

This grid includes every possible fraction. Some will be there more than once – for example, 1/2, 2/4, 3/6 and so on are all really the same fraction – but the important thing is that we have caught them all.

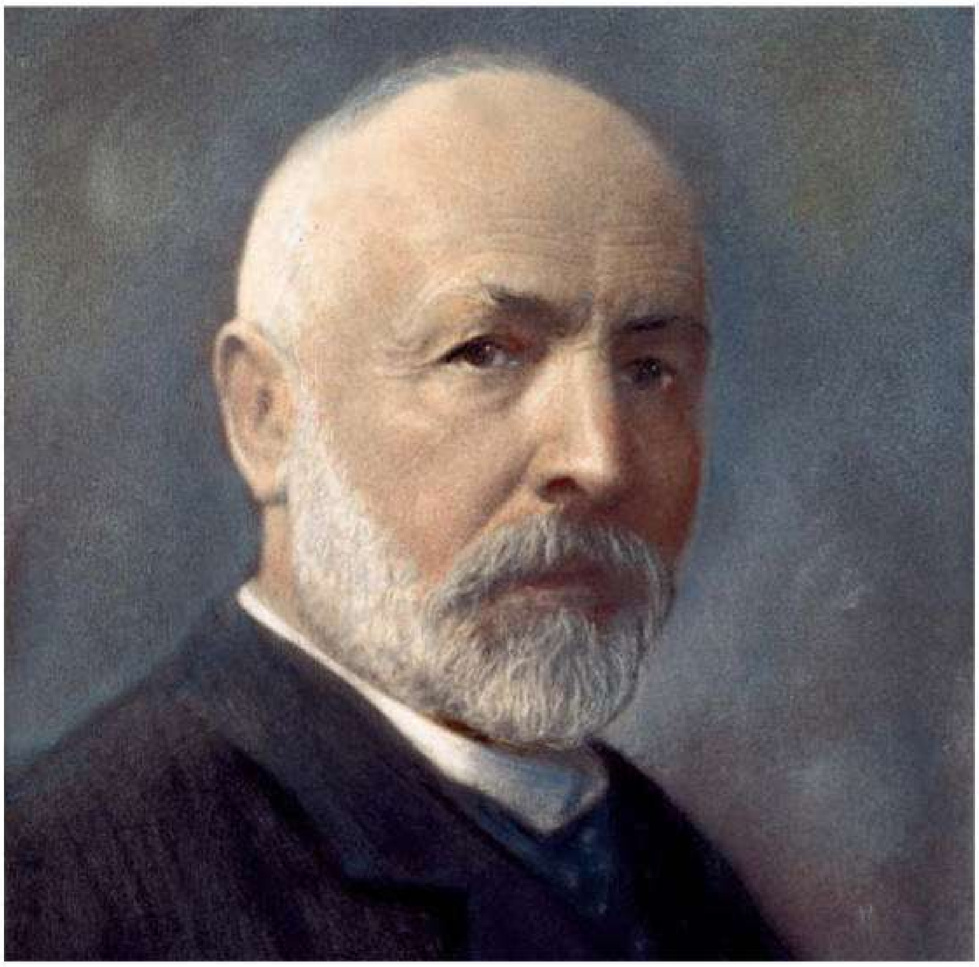
GOING ON FOREVER

This set is as big as the positive rational numbers, and it can be paired with the countables by moving through the grid in a diagonal pattern as shown below and assigning each rational number a countable number in order. This gives pairings (1/1, 1), (2/1, 2), (1/2, 3), (1/3, 4) and so on, and the process can continue forever.

A few technical conditions need to be checked, but essentially this shows that every rational can be nicely paired with a countable – and therefore that the two sets are the same size. This argument accounts only for the positive rationals, but with a few tweaks, it can easily also sweep up the rest.



	1	2	3	4	5	6	7	…
1	1/1	1/2	1/3	1/4	1/5	1/6	1/7	…
2	2/1	~~2/2~~	2/3	~~2/4~~	2/5	~~2/6~~	2/7	…
3	3/1	3/2	~~3/3~~	3/4	3/5	3/6	3/7	…
4	4/1	~~4/2~~	4/3	~~4/4~~	4/5	4/6	4/7	…
5	5/1	5/2	5/3	5/4	5/5	5/6	5/7	…
6	6/1	~~6/2~~	~~6/3~~	6/4	6/5	6/6	6/7	…
7	7/1	7/2	7/3	7/4	7/5	7/6	7/7	…
8	8/1	8/2	8/3	8/4	8/5	8/6	8/7	…
⋮	⋮							



Georg Cantor discovered that infinity comes in infinite varieties

GRANGER/ALAMY

mathematicians care about,” says David Asperó at the University of East Anglia, UK. It covers everything from building the real numbers to constructing a working theory of arithmetic. The hunch was that these foundations just weren’t strong enough to bear the full weight of the infinite tower.

One of the first proposals for a new supporting axiom emerged from a technique called forcing, introduced by Cohen in the 1960s. Loosely, Cohen started with a set of the real numbers of size $\aleph_1$ – with no assumption that this equated to the continuum infinity or not – and then used this technique to cram more into it. Forcing was an extremely powerful tool for building interesting new mathematical sets. But it turned out that you could end up with the real numbers being any size of infinity – not just $\aleph_1$ or the next one up, $\aleph_2$, but $\aleph_{42}$ or anything else. It was simply too powerful a technique to say anything useful about where the continuum infinity lay.

An answer seemed possible by restricting what forcing could do. In 1988, mathematicians Menachem Magidor, Matthew Foreman and Saharon Shelah proposed an axiom called Martin’s maximum, named after set theorist Donald Martin, that could do exactly that. And it gave, finally, an answer to the continuum hypothesis: that it was false. The continuum infinity isn’t $\aleph_1$, but $\aleph_2$; there is a level of infinity between the countable and the continuum. A decade later, in 1999, Hugh Woodin, then at the University of California, Berkeley, suggested another approach, called (*) and pronounced “star”. Like forcing, this also allowed mathematical objects to be built, but in a slightly different way. It, too, said that the continuum hypothesis is false, and that the continuum infinity lies at the third level up, $\aleph_2$.

A new level of infinity?

There is no easy, intuitive example of what might sit between the countable and the continuum, but there are some complicated constructions that we know would do whether or not $\aleph_1$ and the continuum are the same thing. The Hausdorff gap, for example, is a set involving sequences of numbers that has size $\aleph_1$ regardless of the size of the continuum.

Still, with two competing ways to fortify the foundations of mathematics both giving the same answer to the continuum hypothesis, you might think it was game over. But then came another twist that could be loosely characterised as Woodin changing his mind. Both (*) and Martin’s maximum are axioms ›

IS INFINITY REAL?

Mathematics needs infinity. Two of the most practically useful branches of mathematics, trigonometry and calculus, use it, but in such a way that the infinities are conveniently hidden from the real world. You need the infinities involved in both to work out the optimum path of a rocket, but neither the trajectory nor the velocity, or any practically measurable quantity, will ever come close to the infinite. Mathematically, infinity is useful, but does it really exist in the physical world?

In many theories of physics, the appearance of actual infinities is a sign of things going awry. In Einstein’s equations of general relativity, for instance, the “singularity” at the centre of a black holes is an infinitely warped point in space-time; similarly, wind the clock of our expanding, cooling universe back some 13.8 billion years and you reach the point of the big bang where it is supposedly infinitely dense and hot. Actually, however, we know that general relativity breaks down when we reach these tiny, extreme scales where quantum theory also comes into play. The infinities seem to be the equivalent of a mathematical shrug: don’t know what’s going here, sorry.

The quantum field theories that underlie the standard model of particle physics provide another example. These were once filled with nonsensical predictions that, for example, the mass and charge of an electron were infinite. Over decades, physicists have steadily managed to remove many of these infinities, creating today’s highly successful model. If the standard model can one day be unified with general relativity to give a complete picture of the universe, perhaps the infinities will disappear completely – or of course, perhaps they won’t.

DAVID PARKER/SCIENCE PHOTO LIBRARY

Has time finally been called on the continuum hypothesis?

that help mathematicians to build infinite sets from the bottom up. Woodin instead started to advocate a top-down approach that he called ultimate L. This is a variant of an idea first suggested by Gödel, and is akin to building an observation deck high in the infinite tower to help you see what is going on down below. From above, ultimate L reaches the opposite conclusion to the others – it says that the continuum hypothesis is true.

Top down or bottom up, ultimate L, Martin's maximum or (*)? Each of these approaches has its advantages and disadvantages, and it is up to their proponents to demonstrate why their idea is the right one. That is where one camp appears to have just edged in front. In 2021, Asperó and Schindler proved that if you are in the bottom-up camp, you don't have to choose between Martin's maximum and (*). With a few technical tweaks, if you choose Martin's maximum as your additional axiom, that implies (*) is a legitimate approach too.

The proof took the best part of a decade to complete. Asperó and Schindler had originally hit on the idea in 2011, but when they first published their workings, Woodin spotted a mistake. Yet the revised proof has certainly rocked the world of mathematics. Not only does it convincingly fuse two approaches, but the very fact that they turn out to be so intertwined is seen by some as evidence that this is the right answer – and that Cantor was ultimately wrong in his conjecture. As Juliette Kennedy at the University of Helsinki, Finland, told *Quanta* magazine when the revised proof emerged: "It's one of the most intellectually exciting, absolutely dramatic things that has ever happened in the history of mathematics."

"It's remarkable," says Woodin. "Typically, when two completely different lines of investigation converge on the same thing, that's taken as evidence for truth." Despite that, he still isn't convinced, believing that ultimate L is a neater and better way forward. But his approach is still mired in the details. Since he first proposed the idea in 2010, he has yet to come up with the proof that ultimate L really works as he thinks it should. "I'm optimistic the proof is near," he says. "The trouble is the community is getting very tired of me saying that. I've been optimistic for several years now."

In some ways, an answer to the continuum hypothesis and the best way to firm up the foundations of mathematics seems closer than ever before. But it could just be an illusion. That is the thing with the infinite: you tend never to reach the end. ▮

Accountably uncountable

The real numbers – every number that can be expressed as a decimal – aren't a countable set. This means that however you pair them up with the countable numbers, you will always have some left over.

The proof goes something like this. First, imagine creating a table with all the countable numbers, 1, 2, 3, 4 and so on up to countable infinity, and pairing them in a second column with any randomly chosen real number with an infinite number of decimal places.

Now create a new number. Find your first digit by adding 1 to the first digit of the first real number in your list, and your second by adding 1 to the second digit of the second real number and so on. Here is an example:

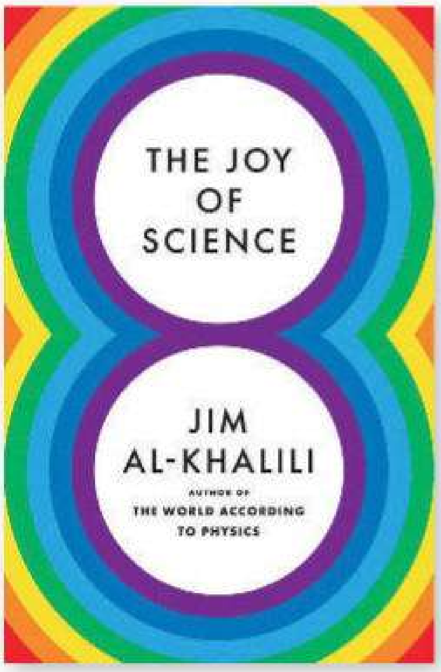
1	**3**.153778425…
2	0.**7**36785323…
3	7.2**7**0286930…
4	42.3**4**603146…
…	…

The new number is **4.885…**

This process ensures our new real number with infinitely many decimal places has at least one digit different from every number in the (countably infinite) list, so can't be in it. This reveals a contradiction: not every real number was on the original list paired off with all countable numbers. Therefore, these two sets don't have the same size: there are more real numbers than countable numbers.

"Two proofs converging on the same answer suggests that answer is right"

Timothy Revell is *New Scientist*'s deputy US editor



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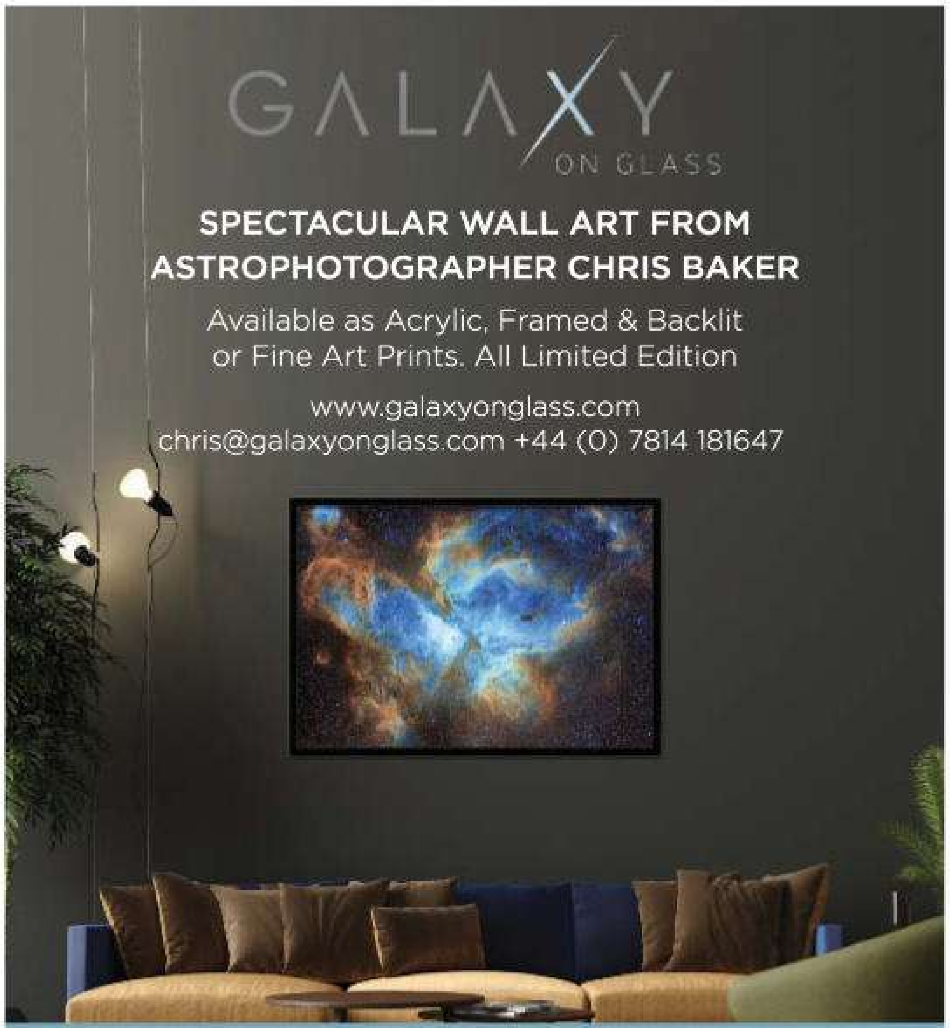
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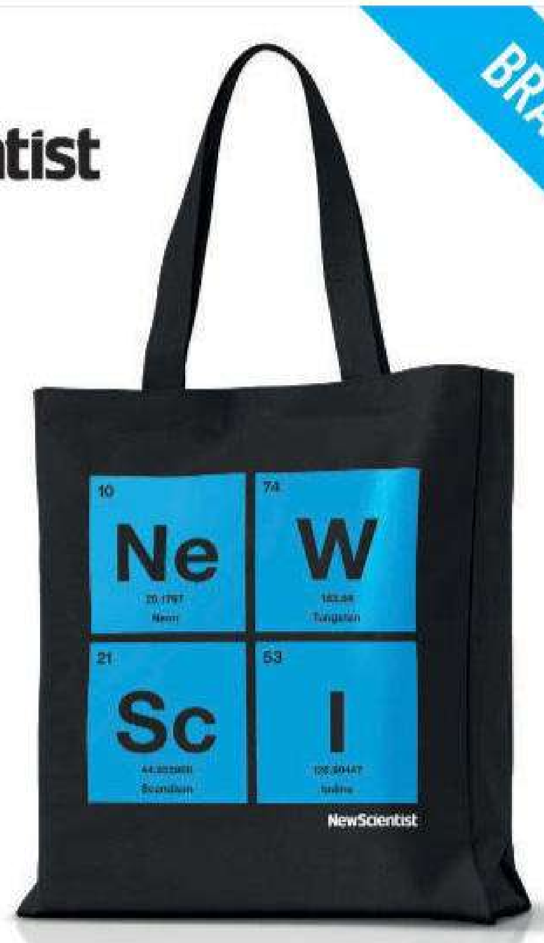

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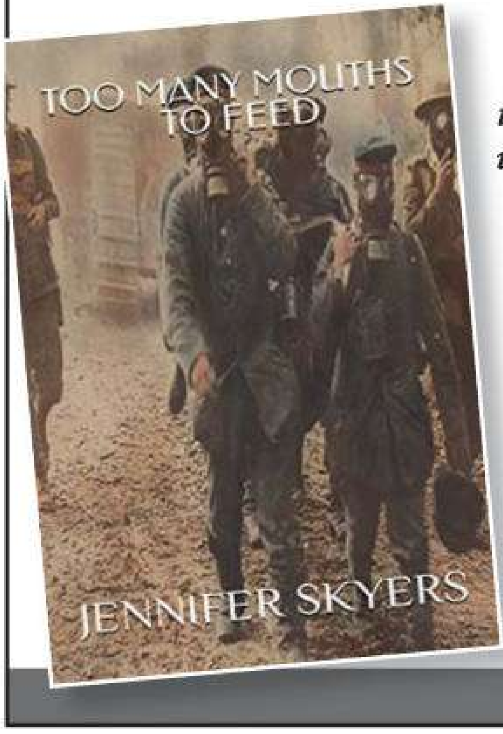

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Better by design

Neuroscientists are turning their hand to interior design, helping us to create homes that don't just look nice, but boost our physical and mental health too, finds **David Robson**

YOU might recognise the sensation from visits to a friend's house – the feeling that a space is good for you. Perhaps it is a sense of profound relaxation, as if you left your worries at the door. Or you may have found the perfect office space that leaves you buzzing with creative ideas. Yet try to explain why you felt that way, or recreate those effects at home, and you fall short.

According to the ancient Chinese practice of feng shui, there are rules of harmonious living that affect the flow of energy through your body, and many modern design gurus take a similar line, dishing out guidance in lifestyle magazines and Instagram accounts. They advise on the shape of rooms, materials in furnishings, colours on walls and organisation of books – it may make your home look good, but does it make you feel good?

While there is nothing wrong with going with your gut when it comes to decor, there could be a better way to make design choices. A growing number of neuroscientists are collaborating with architects and interior designers. With carefully controlled experiments using objective physiological and psychological measures, they are starting to systematically test the influence of design elements on brain and body.

The work couldn't be timelier. The rise of remote working has meant more time at home for many. Whether you want to boost your mood, lower your blood pressure, decrease your bad habits or ease the burden of dementia (see "Dementia-ready homes", page 46), this research can provide evidence-based strategies to optimise your living space for your physical and mental health.

The roots of this work lie in a field called neuroaesthetics. In the 1990s, neuroscientists began to explore the brain processes underlying our sense of beauty in art and music. They have shown, for instance, that the brain's amygdala preferentially processes blurred images, showing heightened activity before we are even aware of what we are seeing. This is thought to be due to the region's role as an early warning system, detecting threats in the peripheries of our vision (which are inherently blurry). The soft contours of impressionist art trigger this pathway, offering a hotline to the brain's emotional processing that bypasses our conscious preferences and triggers an emotional response.

Over the next two decades, the focus of attention expanded from fine art to design – spearheaded by a conference at the faculty of architecture at the University of Dresden, Germany, in 2010. "We got to hang out with all these architects and designers," says Oshin Vartanian, a psychologist at the University of Toronto. "We left this meeting with tremendous enthusiasm that this was something to go after."

Much of the initial research explored the way our evolutionary history may have shaped our reactions to certain indoor spaces. According to one branch of evolutionary psychology, which biologist E. O. Wilson referred to as the "biophilia hypothesis", we are drawn to living things – such as the sight of foliage and fruit or the sound of birds – and that this tendency has, in part, a genetic basis. This love of nature would have been adaptive, since other organisms could be sources of food or danger. Consequently, our brains still find

LEONIE BOS

natural scenes effortlessly fascinating – they can capture our attention without us having to deliberately focus on them. According to "attention restoration theory", this can help to recharge the mind when it is stressed. Experiments in adults and children have shown that environments that stimulate unconscious attention allow parts of the brain responsible for directed attention to rest and recover from mental fatigue. "The effects are similar to those of meditation," says John Spengler, a professor of environmental health and human habitation at Harvard University. As a result, we find scenes from nature particularly restorative – and designs that incorporate natural elements into homes and offices should have knock-on benefits for our physical and mental health.

Indeed, many studies now support that idea. Hospital patients whose rooms overlook natural settings tend to need lower doses of painkillers, and leave hospital earlier, than those whose windows look out over a brick wall, for instance. Other research has found that green views – in this case, of a flowering rooftop meadow – seem to restore students' ability to mentally focus, compared with those looking out over a bare roof.

Faking it

We don't all have the luxury of a lush vista, of course. But evidence is building that a naturalistic interior design can bring about the same benefits, even if we live in a concrete jungle.

Some of the most compelling comes from Jie Yin at Tongji University in Shanghai, China, who has used immersive virtual reality (VR) environments to test the benefits of different biophilic designs.

Spengler, Yin and their colleagues first created four separate office designs. One was a standard room without any natural elements. The second had an outdoor view and shelves with houseplants. The third had wallpaper with foliage print and a sculpture taking the form of a tree's branches. The fourth was similar to the third, with the addition of several real plants dotted around.

They then asked participants to navigate the VR rooms for about 10 minutes while wearing monitors that measured their cardiovascular activity. Compared with the standard room, all the biophilic offices reduced blood pressure. It didn't seem to make a big difference whether the contact with nature came through a window or whether it was part of the interior design. ›

Dementia-ready homes

A new approach to housing design is especially important for the UK's ageing population. Last year, the UK government released a report outlining the need for more "dementia-ready" housing. Recommendations include guidelines on improving community support, but there are practical design tips too. These include ensuring that signs in communal areas avoid icons, such as the green running man for the exit, which might be confusing for people with memory lapses.

They also recommend the strategic use of recognisable landmarks, such as trees and street furniture. Landmarks can also be used inside the home, such as a large pot plant or a striking painting. Brain studies have shown that good navigation strongly relies on our ability to recognise and remember landmarks, so increasing the number of permanent landmarks inside and outside the home should be helpful for people experiencing cognitive decline.

Dementia-ready housing could also incorporate some biophilic elements inspired by nature (see main story), together with increased access to natural light. There is strong evidence that this can help to reduce the incidence of depression, which is generally higher among people with dementia.

DIMABERLIN/SHUTTERSTOCK

Testing the idea further, Yin, Spengler and their team have since measured the ways that interiors can help people to recover after a mildly stressful event. Using a similar set of VR rooms, participants had to perform difficult mental arithmetic and take memory tests with a loud buzzer sound signalling incorrect answers. Once again, he found that the natural elements helped the participants recover after the challenge – resulting in a more rapid decline in blood pressure, compared with those exposed to the standard office design.

These were only short-term experiments, but quicker stress recovery could be a big deal for overall health in the long term, since elevated blood pressure is a known risk factor for cardiovascular disease. At the very least, this research might encourage us to source a few more house plants. But there are many ways in which we might incorporate biophilic elements into our homes and offices – including a greater use of natural materials.

For instance, Xi Zhang at Shanghai Jiao Tong University in China and his colleagues asked participants to work on a laptop for around 30 minutes in rooms in which interior walls were either exposed wood or painted white. Overall, the participants reported feeling much happier in the rooms with wood on display, and felt less fatigued at the end of their work.

Wood, it turns out, appeals to several of our senses. Other studies have shown that the feel of wood decreases blood pressure compared with aluminium and plastic, which both tend to increase blood pressure. There is even some early evidence that the mere smell of certain woods can be relaxing.

Make space

That's the decor sorted, but perhaps our evolutionary history should also play into the way we design the layouts of our buildings. If you have ever found open-plan living appealing, you might be unknowingly tapping into something called "habitat theory". This is the idea that we have a preference for larger, open spaces dotted with smaller areas of cover because of the fundamental visual properties of our ancestral home, the savannah. "The idea is that it would have been beneficial for you to be able to see across a vista, so that you could react easily if a potential source of danger was approaching," says Vartanian. "But it had to be paired with somewhere to hide."

Vartanian says there is now good evidence that these biases shape our responses to certain spatial designs. Views of smaller, enclosed spaces tend to produce heightened activity in the brain's anterior midcingulate cortex, which typically responds to threat, he says. And when participants view photos of open-plan rooms in brain scanners, the images preferentially trigger activity in brain areas involved in visual exploration – a much more relaxed state of mind.

Once again, these differences could have important physiological consequences, particularly when you are already feeling anxious. Using VR, Lars Brorson Fich at Aalborg University in Denmark and his colleagues asked people to take part in a challenging public-speaking task within an enclosed or open-plan room. They found that the participants in the open space showed less severe spikes in the stress hormone cortisol, compared with those in the closed space.

That could be worth considering if you are planning a home working area and have the luxury of open-plan living. In the short term, opening up interior space may just lead you to feel a bit less on edge. After all, too much stress has been linked to numerous physical and mental conditions, including obesity and cardiovascular disease.

Neuroscientists don't have all the answers, however. Something you might want to leave to instinct is the temperature of your environment, for instance. Small studies

Natural elements – real or fake – allow the brain to recover from mental fatigue

Change your light to think better

Unless we are creating soft lighting for a romantic meal, it is easy to ignore the subtle ways that lights can influence our mental state. But a series of studies have shown that it can profoundly influence thinking.

Anna Steidle and Lioba Werth at the University of Hohenheim in Germany, for instance, found that bright lights – of 1500 lux – encourage a greater sense of self-awareness, which, in turn, leads to more reflective thinking.

Dimmer lights, in contrast, tend to make us less self-conscious – which psychologists have discovered can promote a more experimental mindset that suits freewheeling problem solving. Participants in dim settings found it easier to solve the famous candle problem, for example, in which they are asked to fix and light a candle on a wall so that the wax doesn't drip on the floor, using a box of matches and a box of thumbtacks as their only tools. The correct solution requires emptying the box of thumbtacks, placing the candle inside and then using a thumbtack to attach the box to the wall.

show that people are better at performing tasks that test working memory – your ability to hold and manipulate information in your mind – when a room is at their preferred temperature, potentially leading to improvements in efficiency and productivity. Of course, the ideal temperature may be a trickier call when sharing a home-working space with a partner.

Your unique preferences can also be let loose when it comes to colour. While you might have heard that certain colour schemes can influence cognitive performance, larger analyses tend to suggest the effects are minimal. On the other hand, there is strong evidence that the lighting schemes we use can influence things like creativity – so dimmer switches might be a good investment (see "Change your light to think better", above).

More generally, you should be mindful of the overall visual complexity that you are creating; natural designs may be soothing, but can be in danger of looking too chaotic without some kind of organising principle, such as symmetry or repetition. Such small tweaks – while seemingly irrelevant to human behaviour – could influence our actions in profound ways, says Ingrid Fetell Lee, author of *Joyful: The surprising power of ordinary things to create extraordinary happiness*.

> **"People were happier and less tired in rooms with wood on display"**

She highlights a study by researchers at the University of Chicago, in which participants were shown various designs, some of which looked visually chaotic and jarring, with asymmetrical features. "They weren't dirty or littered," says Lee. "They were just architecturally funky." Incredibly, participants shown chaotic designs were more likely to cheat when grading themselves on a maths test, compared with people who had viewed more ordered images. There is even evidence that orderly environments can encourage healthier eating, too.

We can only read so much into these findings, which examine the short-term effects of order in our environment, but studies investigating the opposite end of the spectrum – clutter – also support the idea that an ordered home has benefits. There is a significant link between procrastination and clutter in your environment, for instance. Several experiments show that a cluttered home is also linked to increased levels of cortisol throughout the day. It may be that the clutter itself isn't the stressor, but the thought of having to keep up appearances. Regardless, creating a bit of visual order seems worthwhile. Even something as simple as reorganising your books according to colour can be a way of creating more order in a room, says Lee.

Finally, it may be helpful to find ways to fine-tune the ambience, so that you feel you have more control of your environment. One study at an insurance company in Wisconsin used technology that allowed individual employees to control the lighting and ventilation of their workspace, which significantly increased productivity by a few per cent. This may, in part, be due to greater physical comfort – but further studies suggest that the mere illusion of control over our surroundings can help us to feel better, even when the ambience itself doesn't substantially change.

And while you are thinking about all these changes, don't forget the importance of individuality. While environmental psychology might offer solutions for reducing stress, instilling discipline and improving productivity, remember there are always exceptions. So if that oversized, shiny Harley-Davidson motorcycle on display in the corner of your living room brings you a spark of joy, it is OK to occasionally drop the rulebook (as long as you quickly return it to its correct position on your colour-coordinated bookshelf). ▮

David Robson is author of *The Expectation Effect: How your mindset can transform your life*

30 by 30

A bold plan aims to set aside 30 per cent of global land and sea area for nature by the end of the decade. Can it work, asks **Graham Lawton**

IT IS perhaps inevitably being trailed as a last chance to avert disaster. But when the world gathers in Kunming, China, later this year to finalise a much-delayed global deal on biodiversity, the fate of the universe's only known biosphere will lie in the negotiators' hands. "We're in crisis mode," says Eric Dinerstein, former chief scientist at conservation group WWF. "We have 10 years before we surpass critical tipping points that would lead to irreversible biodiversity loss."

At the centre of the deal under negotiation is a new, ambitious target that goes far beyond previous, failed commitments to protect biodiversity. Catchily titled "30 by 30", it would commit nations to setting aside 30 per cent of Earth's land and seas for nature by 2030. For many conservation biologists, it is a breakthrough even to see it on the table. But nerves are also jangling. Will 30 by 30 make it through – and if it does, will the world act, and will it be enough?

Biodiversity is important. Even if we cannot bring ourselves to preserve it for its own sake, we should at least do so for selfish reasons. Intact nature provides a range of "ecosystem services", from life support, such as clean air and water, fertile soils and pollination, to psychological benefits and protection from climate change, extreme weather and natural disasters – not to mention a reduced risk of "spillover" diseases like covid-19. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services lists 18 separate benefits of biodiversity.

Yet we have hardly taken heed. The Convention on Biological Diversity (CBD) was set up following the 1992 Earth Summit in Rio de Janeiro to coordinate efforts to conserve biodiversity, and it has since been signed by every UN member state bar the US. But we have consistently missed the goals it has set. That applies to all 20 of the last lot, agreed for the decade from 2010. Called the Aichi Biodiversity Targets, they covered everything from removing subsidies from activities harmful to biodiversity to halving habitat loss and adopting sustainable farming practices.

But they weren't a total write-off. One salvageable achievement was on "protected areas", such as conservation sites and nature reserves. The concept of ring-fencing areas was first proposed in 1972 by ecologist brothers Eugene and Howard Odum. "It would be prudent to strive to preserve 50 per cent [of Earth]," they argued. It has since become a cornerstone of conservation policy. "We know that protected areas, when they're done right, are really important for preserving biodiversity," says Paul Leadley at Paris-Saclay University in France.

The first iterations of such "area-based conservation" focused on preserving "representative samples" of all known ecosystems, on the basis that there was an ethical and practical imperative not to let things go extinct, but that room was also required for human development. This led to an initial suggestion that around 10 to 12 per cent of Earth's surface should be left to nature's devices. A target set by the CBD of at least 10 per cent by 2010 was missed, but was partially upped in Aichi to 17 per cent on land and 10 per cent in the ocean by 2020. These targets were again missed, but by 2020, 15 per cent of land and 7 per cent of the sea was protected. Flushed with this sort-of success, the CBD declared the goal "partially achieved".

LUIZ CLAUDIO MARIGO/NATUREPL

The Guapiaçu Ecological Reserve protects threatened Atlantic Forest landscape in Rio de Janeiro state, Brazil

Yet even as early as 2010, many biologists were arguing for far higher targets, based on a realisation that representative samples weren't enough. Effective conservation meant keeping species in their natural distribution and abundance, building buffers against extinction and enabling the whole ecosystem to function, while keeping ecosystem services healthy and building resilience to environmental changes such as global warming.

That requires more land. "There are many studies now showing that if we want to protect not only the biodiversity and all the benefits that it provides to humanity, including carbon sequestration and storage and freshwater provision, we need about half of the planet in its natural state," says marine biologist Enric Sala at the National Geographic Society. The CBD cites eight key papers in support of a 30 per cent minimum. Most studies settle on 50 per cent plus and some go as high as 80 per cent. A few dip below 30 per cent, but always with disclaimers. Importantly, says Stephen Woodley at the International Union for Conservation of Nature (IUCN), there are no studies showing that healthy biodiversity can be maintained with much less than 30 per cent.

That's why the 30 by 30 ambition has become so central to the negotiations ahead of COP15 in Kunming, the latest CBD conference. It would mean roughly doubling conserved land areas and quadrupling protected marine areas. This is an extremely ambitious target, says Leadley, and there are all sorts of nagging fears: that 30 by 30 will be watered down or dropped from the final text; that if it does make the cut, it won't be reached; and that if it is reached, it won't achieve its stated goal of effectively protecting biodiversity.

"The 30 by 30 target is an absolute must-have for any global agreement to be successful," says Brian O'Donnell, director of Campaign for Nature, a global coalition of conservation organisations. "It must remain in the final agreement." The draft has already been through considerable peer review, but that doesn't mean it will survive final negotiations among high-level government representatives. "As we get closer to signing, I suspect there'll be some resistance," says Woodley.

> **"30 by 30 is a must-have for any agreement to conserve biodiversity"**

That resistance is likely to come from low-income countries where most of the planet's remaining biodiversity resides. Their beef is that high-income nations have already wrecked their own biodiversity in pursuit of economic growth, and now want them to resist doing the same. "Countries like Brazil are saying: 'OK, you want me to protect the Amazon – what's in it for me?'" says Woodley. "They're stating that rather forcefully and they're not wrong." The negotiations will quite possibly hinge on a sticking point familiar from climate negotiations: the › readiness of higher-income countries to compensate biodiversity-rich lower-income countries for doing much of the heavy lifting. “It’s all about the money,” says Woodley.

Some money does already flow. The US aid budget, for example, helps to fund Brazil’s biodiversity conservation work in the Amazon rainforest to the tune of $80 million over 10 years. In 2015, the Seychelles had some of its debt written off in exchange for protecting its sensitive marine environments. But auguries from other multilateral international negotiations aren’t good. At the 2015 Paris climate talks, richer nations agreed to pay poorer ones $100 billion a year to mitigate the effects of climate change. The money has yet to appear in full. “When, precisely, are we peoples of the south going to be compensated for these ravages that have been caused by the northern hemisphere?” asked Madagascar’s foreign minister, Djacoba Liva Tehindrazanarivelo, at the recent One Ocean Summit in Brest, France. “Give us our money back.”

If some agreement over financing can be reached, there is just about enough pristine nature available to protect 30 per cent, says Woodley. According to Dinerstein, now at the Resolve non-governmental organisation in Washington DC, about half of the land surface is either untouched or relatively untouched by human influence, above all in the Sahara desert, the Amazon basin, the Australian outback and the tundra and boreal forests of the Arctic (see map, right). When you add in areas home to Indigenous peoples that are generally high in biodiversity (see “Indigenous protectors”, left), we might even have technically reached the 30-by-30 target already.

What 30 by 30 would end up meaning, however, is open. It is currently framed as a global goal, but could become a series of national ones, with each country setting aside 30 per cent of its land and sea area. If so, extensive ecological restoration will have to be carried out in nations such as the UK that have little intact biodiversity left, says Leadley.

But for all the pitfalls, there is growing oomph behind 30 by 30. More than 100 nations, including many low-income ones, have joined either the High Ambition Coalition for Nature and People, which is committed to 30 by 30 on land and sea, or the Global Ocean Alliance for 30 by 30 at sea, or both. “We’re excited that momentum is actually growing for this target,” says O’Donnell. That said, some large countries housing a lot of biodiversity, including Brazil, China, Russia, Indonesia and the US, have yet to sign up.

But while it seems obvious that protecting large segments of Earth’s surface will also safeguard biodiversity, there is more to it than brute numbers. For a start, protecting an area

Indigenous protectors

Much of Earth’s most biodiverse land surface is already extremely well-protected – it just isn’t formally recognised as such. Across the world, from the Arctic to the South Pacific Ocean, some 80 per cent of Earth’s remaining biodiversity is thought to be in territories managed and owned by Indigenous peoples.

About 7 per cent of the land listed in the World Database of Protected Areas maintained by the International Union for Conservation of Nature (IUCN) and the United Nations Environment Programme is Indigenous, but another 17 per cent of Earth’s surface is owned, occupied or managed by Indigenous people and local communities, says Eric Dinerstein, former chief scientist at WWF. “Indigenous groups do a better job of protecting biodiversity than governments do,” he says. If you add it all up, he says, we have arguably already exceeded the crucial target of protecting 30 per cent of Earth’s land surface (see main story).

The problem is that Indigenous land claims often aren’t recognised by governments. “We should be doing everything we can to finance and empower Indigenous groups to have sovereignty over their lands,” says Dinerstein. “That would be the cheapest thing to do by far, and have the biggest effect.”

Indigenous people are often under-represented and marginalised at international environmental summits. At last year’s IUCN World Conservation Congress in Marseilles, France, an officially organised group of Indigenous communities participated for the first time. At the COP26 climate talks in Glasgow, UK, though, they were once again pushed to the sidelines.

Biodiversity negotiations have traditionally been more inclusive. Since 1996, the International Indigenous Forum on Biodiversity has had a seat at the negotiating table, and a spokesperson for the Convention on Biological Diversity says that it is “committed to the effective participation of Indigenous peoples… in recognition of their fundamental role in the successful implementation of the new framework”.

Indigenous peoples’ participation was also a key part of the Aichi Biodiversity Targets, which ran from 2010 to 2020. Along with all the others, that target was missed, though there were some isolated wins: in 2018, for example, Costa Rica enshrined a mechanism to consult its Indigenous groups over any action that would affect them. Brian O’Donnell at the Campaign for Nature says that negotiations have made progress on Indigenous rights, but there is still room for improvement. And of course, as many Indigenous people know only too well, just because a deal is signed doesn’t mean it will be honoured.

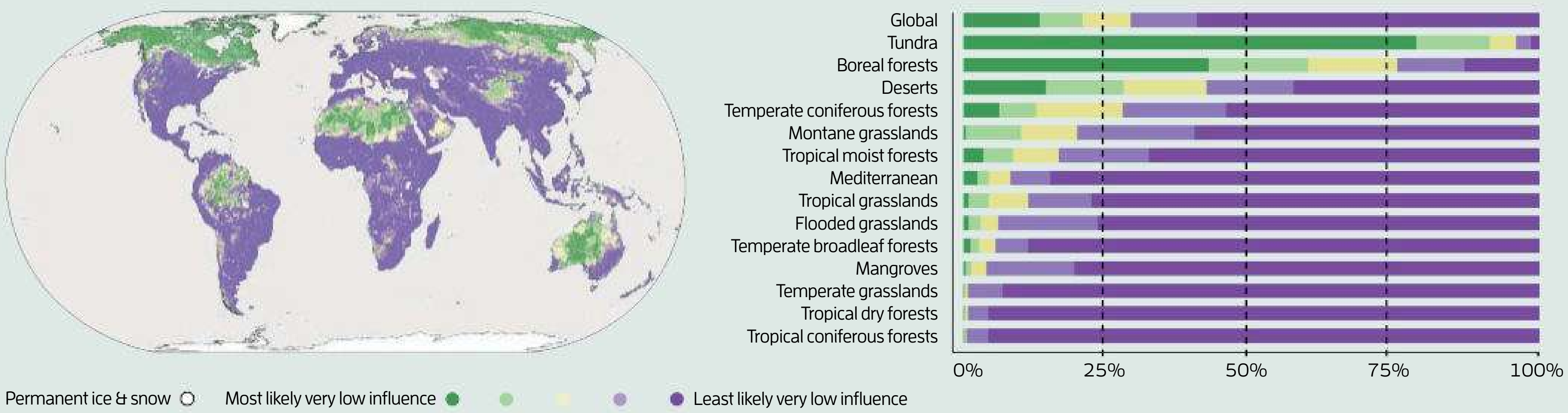
A ranger patrols the Nairi-Awari Indigenous territory in Costa Rica in 2021

EZEQUIEL BECERRA/AFP VIA GETTY IMAGES

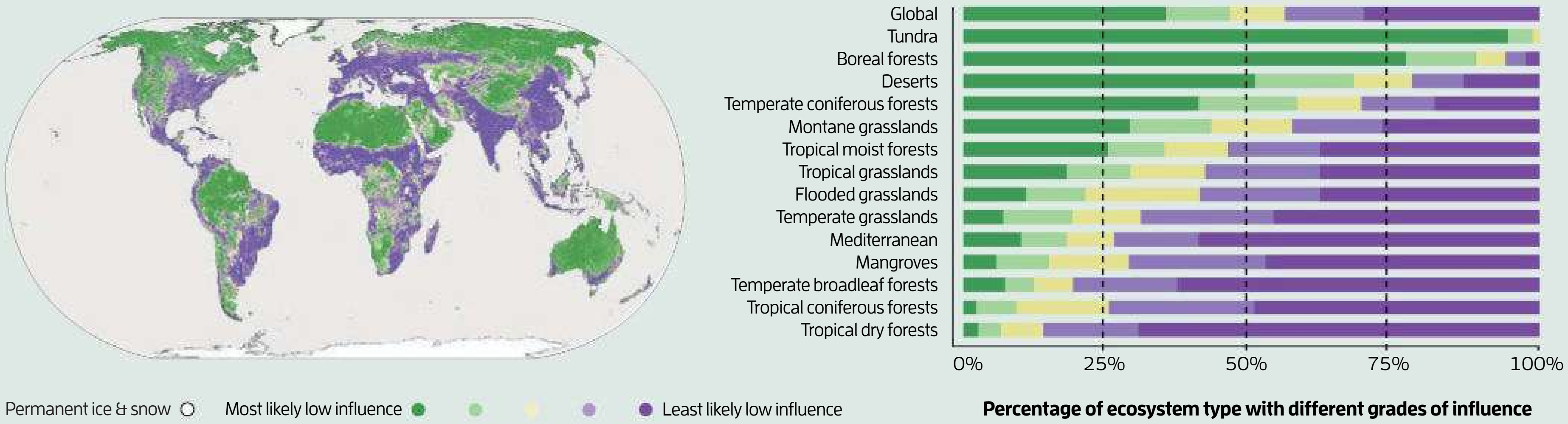
Where the wild places are

There is no one way to quantify human influence on nature, but combining different methods allows us to produce maps of areas of Earth's surface where human influence is low and very low. Different types of ecosystem differ vastly in the proportions deemed to be low or very-low influence.

Very low human influence



Low human influence



SOURCE: Riccio et al. doi.org/10.1111/gcb.15109

that has seen very little human influence will not necessarily do much to help biodiversity. "Biodiversity is distributed very unevenly on planet Earth," says Woodley. It is equally important to preserve the right places, to manage them well and to connect them up where possible to increase their effectiveness.

All of these goals were in the Aichi targets and are in the draft of the new ones. This is, in part, why the 20 Aichi targets were missed, says Piero Visconti at the International Institute for Applied Systems Analysis in Laxenburg, Austria. Too many nations gamed the system by establishing protected areas in places that were "disproportionately unimportant for biodiversity", he says, such as in Alaska and the arid Australian outback, and too many new areas were "paper parks" with boundaries drawn on maps but little or no management or actual protection put in place.

Indeed, even though areas under protection have increased since 2010, protection of biodiversity hasn't increased proportionately, says Sean Maxwell at the Centre for Biodiversity and Conservation Science at the University of Queensland in Australia. The fear is that, even if 30 by 30 makes the final cut, new protected areas will be similarly toothless – and there is little that can be done to prevent it, says Woodley. Though the IUCN has laid down formal definitions of what constitutes protection, and has got better at measuring and monitoring, "it doesn't stop countries from cheating, it can't solve the corruption that lies at the heart of the issue", says Woodley.

Resourcing is a real concern, says Leadley, and the danger is 30 by 30 might backfire if countries spread already-scarce resources even more thinly. Negotiators may also smuggle some cheats into the treaty, such as allowing heavily managed forests or even palm plantations carved from richly biodiverse tropical rainforests to be counted towards the target. "That's false accounting, and that would be tragic," says Dinerstein.

Ultimately, achieving 30 by 30 relies on so many things that have gone wrong in the past going right in the future that it would be foolish to invest too much optimism in it, he says. And it is just one of 21 targets in the draft treaty. "It is an important part, but it's largely insufficient to achieve the overall objectives," says Leadley. We also need to make sure other causes of biodiversity loss are managed, he says – things like climate change, pollution and invasive species that don't respect the boundaries of protected areas.

And if the CBD process were all we had, we would be right to be worried, says Dinerstein – but it isn't. "I think change is going to come from a coalition led by scientists, young people, Indigenous peoples and local communities and by civil society that will force governments to act," he says. "I'm optimistic that we can save life on Earth. It takes crises for humanity to respond, but we do respond." ▮

Graham Lawton is a feature writer for *New Scientist*

The back pages

Puzzles
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***Almost* the last word**
Does food cooked in a microwave taste inferior? p54

Tom Gauld for *New Scientist*
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Twisteddoodles for *New Scientist*
Picturing the lighter side of life p56

The science of cooking

Get into ginger

The subtle chemical complexity of ginger makes it an astonishingly versatile, and health-boosting, ingredient, says **Sam Wong**

Sam Wong is assistant news editor and self-appointed chief gourmand at New Scientist. Follow him @samwong1

What you need

Per serving:
30 grams ginger
200 millilitres milk
2 teaspoons sugar

CHAROEN KRUNG PHOTOGRAPHY/SHUTTERSTOCK

WITH its citrusy aroma and mild heat, ginger is a phenomenally versatile ingredient used in both sweet and savoury foods. This month, I have learned how to use an unexpected property of ginger to create a delicious dessert.

Ginger's prickly flavour comes from a compound called gingerol, which has a similar structure to capsaicin, the molecule that gives heat to chilli peppers. It binds to the same receptor protein, TRPV1, in nerve endings that stimulates the sensation of heat and pain, albeit more mildly.

Preparing ginger in different ways can increase or decrease its potency by transforming gingerol into other molecules. When cooked, gingerol becomes zingerone, a molecule that activates TRPV1 more weakly and has a sweeter aroma. Drying ginger changes gingerol to shogaol – which is more akin to capsaicin – and stimulates pain receptors about twice as strongly.

Ginger has been widely used as a traditional medicine since ancient times. Several clinical trials have found that it is effective at preventing nausea and vomiting, and gingerol is thought to be the active ingredient. Research also suggests that gingerol could play a role in cancer prevention and treatment.

Ginger is delicious at any time of year, but in the spring, it is worth seeking out young ginger, which has pale, thin skin and pink shoots. It is more tender and juicy than mature ginger and has a milder flavour. It is ideal for making gari, a traditional accompaniment to sushi, consisting of thin slices of ginger pickled in rice vinegar with sugar. Some varieties of ginger turn pink in the acid, thanks to pH-sensitive anthocyanin pigments.

Apart from its pungent and aromatic flavour compounds, ginger also contains zingibain, an enzyme that digests proteins. Be aware of this if you want to use ginger to marinate meat: if it spends more than a few minutes in contact with raw ginger, meat can turn mushy. To prevent this, heat the marinade first to deactivate the enzyme or add acid, such as lime juice, to inhibit it.

Zingibain can be put to use as a substitute for rennet, the enzyme extract used to curdle milk in cheese-making. Milk proteins called caseins are encased in particles called micelles with a hairy surface made of kappa casein. Just like chymosin in rennet, zingibain snips off the hairs, enabling micelles to stick together, coagulating the milk.

You can see this for yourself by making ginger milk curd, a Chinese dessert (this recipe is based on one from the Red House Spice blog). Peel and finely grate the ginger, then press it in a sieve to squeeze about a tablespoon of juice into a bowl. Heat the milk with the sugar to 70°C, then add to the ginger juice. Leave it for at least 10 minutes to set into a solid curd, then serve it warm or cold. ▮

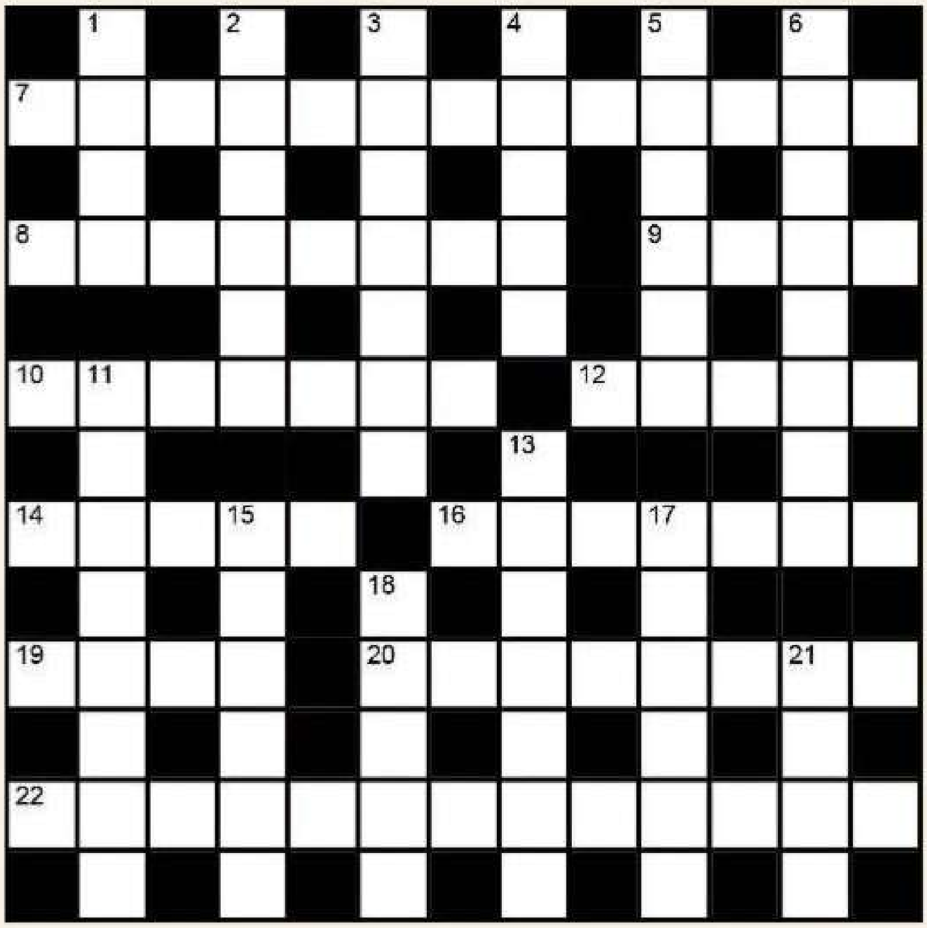
The science of cooking appears every four weeks

Next week

Stargazing at home

These articles are posted each week at newscientist.com/maker

Cryptic crossword #81 *Set by Wingding*



Scribble zone

Answers and the next quick crossword next week

ACROSS

7 Blunder after clinical study with unguided method of problem-solving (5,3,5)
8 Tails indicate Fitzgerald, perhaps (8)
9 Painter drops an Amazonian monkey (4)
10 Herbivore faeces contains two vitamins (7)
12 After 1000 years, cattle show craft (5)
14 Capable leader of academic division (5)
16 Recipe addressed to returning graduate (7)
19 A little emulsion revolutionised basic housing (4)
20 Turn away space invader with automated test equipment (8)
22 Decoy beginning to sway Mr Ed or Bojack? (8,5)

DOWN

1 Sedentary animal expelling carbon via mouth (4)
2 Technical term for gas under Japanese peak (6)
3 Mathematician's home south of US city (7)
4 Antelope put in area with cross (5)
5 Shrub expert on the drink (6)
6 Cloudy streak of fresh cilantro (8)
11 Rise and fall of hoofed animal that has died for good (8)
13 Golf AI developed electronic leaves (7)
15 Spot politician in big house (6)
17 Male sports administrators cultivated plant (6)
18 I run after water supply for jungle dweller (5)
21 Augustus keeps extracted tooth (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #147

1 Sunflowers and dahlias belong to which plant family?

2 The increase in wavelength of X-rays or gamma rays that occurs when they are scattered is known as what?

3 Which geological epoch began approximately 11,700 years ago?

4 Eridu and Larak were city states in which ancient civilisation?

5 Pioneer 10 was the first spacecraft to visit which planet?

Answers on page 55

Puzzle

set by Katie Steckles

#163 Down for the count

In the TV number quiz show *Down for the Count*, four contestants are challenged to combine each of five number cards exactly once to achieve a target number. They are allowed to use standard arithmetical operations +, −, × and ÷ (as well as brackets, if required).

"I'll take five cards from the top row," requested one of the contestants, and the presenter Anne-Marie obligingly revealed these five numbers:

10; 100; 1000; 10,000; 100,000.

The studio computer then generated today's challenge: "Produce a whole number without any zeroes."

No zeroes? Wow. Each of the four contestants thought hard, and after the timer ran out, each announced that they had used the five cards to produce a positive number smaller than 10. All four were different.

Which numbers did they get, and how?

Solutions next week

Heated debate

My partner insists that food cooked in a microwave tastes inferior to that cooked conventionally, but I disagree. Is there really a difference?

Talia Morris
Cape Tribulation, Queensland, Australia
There is a difference between what happens to food cooked in a microwave and when it is heated during conventional cooking.

A microwave cooks food by heating the water molecules in the food, essentially boiling it from the inside out, whereas conventional cooking applies dry heat to the outside of the food, cooking it from the outside in.

Food with a high water content that is cooked in a microwave tastes just like it has been boiled, but if you microwave food with a lower water content, the little moisture it originally had gets steamed out of it, leaving the food unpalatably dry and brittle.

> “These browning reactions create the roasted flavour of coffee and the meaty flavour of seared steak and roasted meat”

Stuart Farrimond
Author of The Science of Cooking, *Trowbridge, Wiltshire, UK*
It depends on what you are cooking. Traditionally steamed vegetables tend to be hard to discriminate from those steamed in a microwave.

Many other foods – especially those that would normally be fried or roasted – will never taste as good in the microwave.

The key to why so many foods taste great is the Maillard reaction. This is an assemblage of countless reactions between amino acids and sugars at temperatures above around 130°C, resulting in a multitude of flavour compounds that convey many lip-smacking aromas and tastes.

These processes (also known as browning reactions) are responsible for bread becoming toast, the roasted flavour of coffee and the meaty flavour of seared steak and roasted meat. Cooking meat in a pot of boiling water will never give it a brown, meaty crust, as liquid water won’t reach 130°C.

In the same way, microwave cooking – which involves the heating of water within the food (to a depth of around 1 to 3 centimetres, rather than “from the middle” as is often claimed) – generally won’t get much hotter than 100°C, the boiling point of water. Hence these wondrous flavours will never be created.

It is, however, a myth to think that microwaves only heat water, and so it is possible to roast nuts in one: spread some nuts coated in a little oil across a microwaveable plate and cook at 1-minute intervals, shaking them each time.

Danny Colyer
Bristol, UK
Before the days of domestic microwave ovens, my parents used to visit the railway station cafe to enjoy a pasty with the deliciously soggy pastry that you only get from heating in a microwave.

Food cooked in a microwave typically retains more moisture than food cooked in a conventional oven, affecting both flavour and texture. Personally, I prefer food heated in the microwave.

Jeremy Jackson
London, UK
Microwaved food is often more evenly cooked, whereas that heated conventionally has a lovely spectrum: rare inside and crunchy on the outside. Imagine bacon or a juicy steak cooked in a microwave. This is why some microwave ovens also have a grill function.

Water, water everywhere – but where and when did Earth’s water form?

ORICHTER/GETTY IMAGES

This week’s new questions

Watery origins **How and where was water first created?**
Bill Richardson*, Riverview, Michigan, US*

Basis of belief **Humans believe in many things, often with no solid evidence. So does belief give us an evolutionary advantage, or is it just something that survived regardless?**
Gerald Lambert*, Northleigh, Devon, UK*

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Patchwork leaf

What is going on to create this amazing multicoloured leaf pattern? (pictured, right)

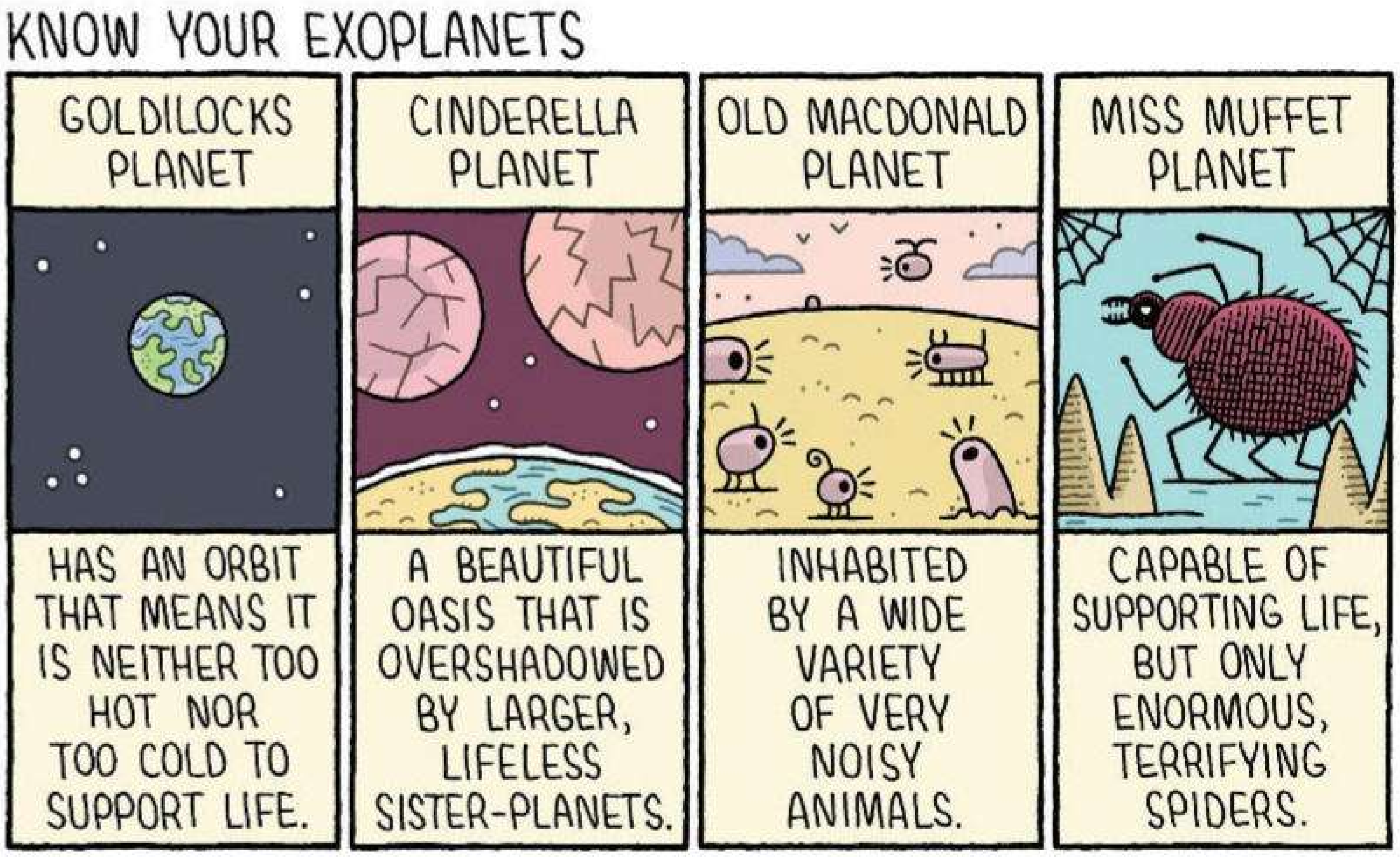
Chris Daniel
Glan Conwy, Conwy, UK
Most leaves are green due to the pigment chlorophyll, but other colours, such as oranges, reds and blues, may also be present due to less efficient photosynthetic pigments like anthocyanins, carotenes and xanthophylls whose main role is to protect the leaf from strong light. The patterned colour of leaves is called variegation – it is a reduction in pigmentation due to inherited (that is, genetic) characteristics of the plant, random mutations or viruses.

The purpose of variegation is a matter of debate. The deficiency of chlorophyll means that the plant may not produce all the energy it needs, but in the plant’s habitat, sunlight may be sufficiently strong for this not to be important. It may be more difficult for a plant with patterned leaves growing in the dappled light of a forest floor to be detected and eaten by herbivores. This survival strategy might outweigh the disadvantage of reduced photosynthesis.

Noel Ellis & Cathie Martin
John Innes Centre, Norwich, Norfolk, UK
Alan Paton & Rafael Govaerts
Royal Botanical Gardens, Kew, London, UK
It is helpful to know the species of plant to be able to suggest causes

Tom Gauld

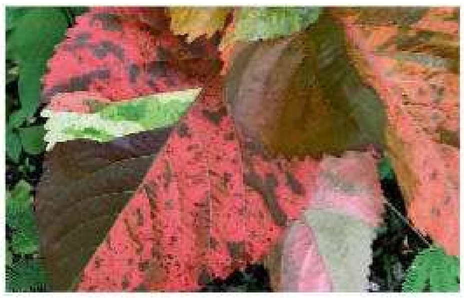
for New Scientist


KNOW YOUR EXOPLANETS
GOLDILOCKS PLANET
HAS AN ORBIT THAT MEANS IT IS NEITHER TOO HOT NOR TOO COLD TO SUPPORT LIFE.
CINDERELLA PLANET
A BEAUTIFUL OASIS THAT IS OVERSHADOWED BY LARGER, LIFELESS SISTER-PLANETS.
OLD MACDONALD PLANET
INHABITED BY A WIDE VARIETY OF VERY NOISY ANIMALS.
MISS MUFFET PLANET
CAPABLE OF SUPPORTING LIFE, BUT ONLY ENORMOUS, TERRIFYING SPIDERS.

for its beautiful variegation. We think the plant pictured is *Acalypha wilkesiana* 'Musaica', also known, appropriately, as Jacob's coat.

There are cultivars of this plant with different shades of green colours (due to the pigment chlorophyll), and others that also have red variegation (due to the pigment anthocyanin). This indicates that different genetic processes are responsible for the red and green colouration, which is why they can occur together in the same leaf.

Thinking about the greenish sector first: white/pale green/dark green variegation is quite common in ornamental plants and is seen most often when one of the three layers of cells that make up a leaf loses the ability to make chlorophyll. However, in the case of the plant in the photograph, the irregular size of the green/pale sections is more reminiscent of the action of a "jumping gene", which is a segment of DNA called a transposable element.



If this element is inserted into a gene required to make chlorophyll or for chloroplast development, this would result in white "mutant" tissue. In parts of the leaf where this element has been excised, a mid-green colour is produced. Other darker sectors can also be seen where this excision has occurred in two overlapping layers of cells.

The leaf pictured also shows variegation in its red anthocyanin pigment (seen in the reddish sections of the leaf). This pigment absorbs excess light and protects the photosynthetic machinery of the leaf.

When the transposable element is excised to give green sectors in a leaf that is also producing red anthocyanins, the sectors appear darker due to the combination of red and green.

As well as this variegation, the leaf also seems to have a "twin spot", where in one sector of cells all anthocyanin production has been lost, and in the next sector the cells are producing more anthocyanin. This can be seen in the left side of the leaf (pictured), where one section looks black and the one above it is pale.

Twin spots consist of two genetically different clones in a background of normal cells. One explanation for the anthocyanin twin spot in the picture is that it resulted from a process known as somatic recombination, where daughter cells are produced from cells in the leaf with different genes for the regulation of anthocyanin production.

We have checked, and there is very little literature available on the variegation in *Acalypha wilkesiana*. The advantage of this lack of scientific investigation, of course, is that we are free to speculate on its causes! ▮

Answers

Quick quiz #147 *Answers*

1 Asteraceae, commonly known as the daisy family

2 The Compton effect

3 The Holocene

4 Sumer

5 Jupiter

Quick Crossword #105 *Answers*

ACROSS 5 Mother, **7** Philtrum, **9** Plumbago, **10** Armpit, **11** Perspiration, **13** Planck, **15** Crater, **18** Edward Teller, **21** By-pass, **22** Taconite, **23** Foreskin, **24** Eye cap

DOWN 1 Phi-meson, **2** Argali, **3** Vitamin C, **4** Stamen, **6** Oil wells, **7** Prozac, **8** Unit, **12** Dementia, **14** Kawasaki, **16** Allen key, **17** Proton, **18** Enamel, **19** Ticker, **20** Typo

#162 Poker dice *Solution*

The opposing faces of a die always add up to 7. Therefore, the die that is on the extreme right must present 5 to the adjoining cube.

The central five dice contribute another 5 x 7 = 35 to the total, regardless of their orientation. The die on the furthest left has 6 on top and 1 on the bottom, and by comparing the orientation of the 2 with that on the die at the right, the furthest left die must present a 4 to the adjoining cube.

Hence the total of the touching faces is: 5+35+4=44.

Hunt the exopet

'Twas the season to be jolly, by which we mean April Fool's Day has been and gone again, before you get too feisty with your falalalalas. Particularly jolly, Feedback found, was a paper posted to the arXiv preprint server by members of the Astrobites collaboration, "First detections of exop(lan)ets: Observations and follow-ups of the floofiest transits on Zoom".

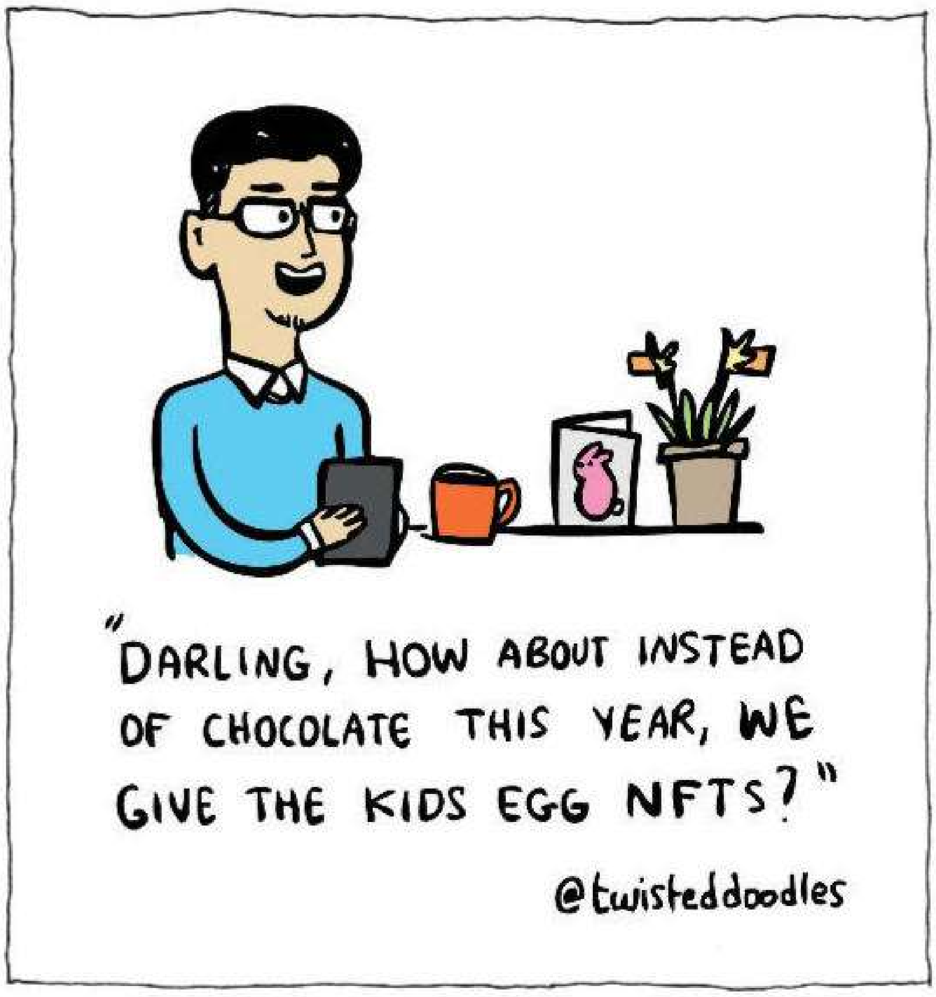
"For more than two years, humanity has been examining new methods of adjusting to work-from-home due to the COVID-19 pandemic. Scientists have tried everything: whipped coffee, sourdough bread, and even questioning whether everything is made out of cake," the astronomers write. They have possibly also spent too long on video-conferencing platforms, as they continue, "Over two years of casual observation, we noted occasional drops in the brightness of a Zoom image of our far-flung collaborators."

But systematic observation brings its own challenges, not least that these transits are less regular than those of exoplanets over the face of their parent star, and – the bane of physicists' lives everywhere – caused not by conveniently spherical objects, but entities irregular in both shape and colour.

At this point, we should say that these are follow-up observations to those made last year of similar objects found rolling around in the local environment by Laura Mayorga and her colleagues at Johns Hopkins University in their paper "Detection of rotational variability in floofy objects at optical wavelengths".

This new analysis of "exopets" inhabiting other homes brings us further, not least in pinning down difficulties observing rarer types, such as Sub-Neptunian Animal Keplerian Extended bodies (SNAKEs) and Dynamically Unstable Coplanar Kepler objects (DUCKs). We salute the creative impetus of lockdown ennui, while fearing this might continue as long as astronomers are trapped on Zoom.

Twisteddoodles *for New Scientist*


"DARLING, HOW ABOUT INSTEAD OF CHOCOLATE THIS YEAR, WE GIVE THE KIDS EGG NFTS?"
@twisteddoodles

Got a story for Feedback?

Send it to feedback@newscientist.com or New Scientist, Northcliffe House, 2 Derry Street, London W8 5TT

Consideration of items sent in the post will be delayed

Absolutely roasting

As Isaac Asimov wrote – not apropos April, but Shakespeare – the secret of the successful fool is that he is no fool at all. This must be why the US National Weather Service chose 1 April to announce on Twitter: "Big changes to our forecast pages! To avoid any confusion between °F and °C, we've converted all of our temperatures to Kelvin. Enjoy!"

Feedback is a fan of absolutism, at least in the scientific sense, and certainly the daily high and low quoted by the NWS at Indianapolis International Airport, 281 K and 273 K, provide a fairer reflection of the relative benignity of Earth's surface temperature fluctuations. But we fear this won't catch on. We ourselves remain fans of what we call the Standard British Mixed Temperature system, in which low temperatures are quoted in Celsius and high temperatures in Fahrenheit, resulting in a handy scale ranging from 0 for cold to 100 for hot. What this loses in logic, it gains in user-friendliness, as long as you don't worry too much about what happens in the middle. Take an umbrella anyway.

News from the future

Feedback joins the world – or everyone in the UK of a certain age or under – in saluting *Newsround*, the BBC news programme for children that recently celebrated its 50th anniversary and remains for many of us the prime source of trusted news that tells it like it is.

Richard Glover has the grumps, however, about a story on the *Newsround* web page claiming that "quantum technology" could be used to charge electric car batteries "in seconds". "I would have thought that this would be more likely to involve extra wiring and some clever switching, than anything quantum mechanical," he says.

Delving into the paper trail so you don't have to, we discover some enthusiastic press releases and a paper from Juyeon Kim and his colleagues at the Institute for Basic Science in Daejeon, South Korea. The good news is that, whereas the charging time of dull old classical batteries shrinks with the number of battery cells, the charging time of whizzo batteries in an entangled quantum state could decrease with the square of the number of cells. The bad news is that no one yet knows how to put a battery in an entangled quantum state.

We fear this might not have changed by 2030, when the UK government plans to ban the sale of new petrol and diesel cars. Still, hats off to *Newsround* for knowing its audience and highlighting a technology that, a bit like nuclear fusion, could well be ready by the time we all grow up.

Lost and found

One area where we can already rely on whizzo quantum speed-ups is in algorithms for searching for things. We are put in mind of this by the happy story of the return to Cambridge University Library of two priceless manuscripts written by Charles Darwin, one containing his famous "tree of life" sketch, in a pink gift bag accompanied by a typed note: Librarian, Happy Easter, X.

Discovered to be missing in 2001, and with various searches of the library's 10-million-odd items turning up nothing, the books were finally reported as stolen in 2020. This exceeds even the time periods we have spent fruitlessly searching for our keys. Sadly, a practical quantum computer that can ask "Well, where did you last have it?" is probably a good few years away too. Still, won't the future be marvellous when it comes? And with that: Reader, Happy Easter, X. ▮

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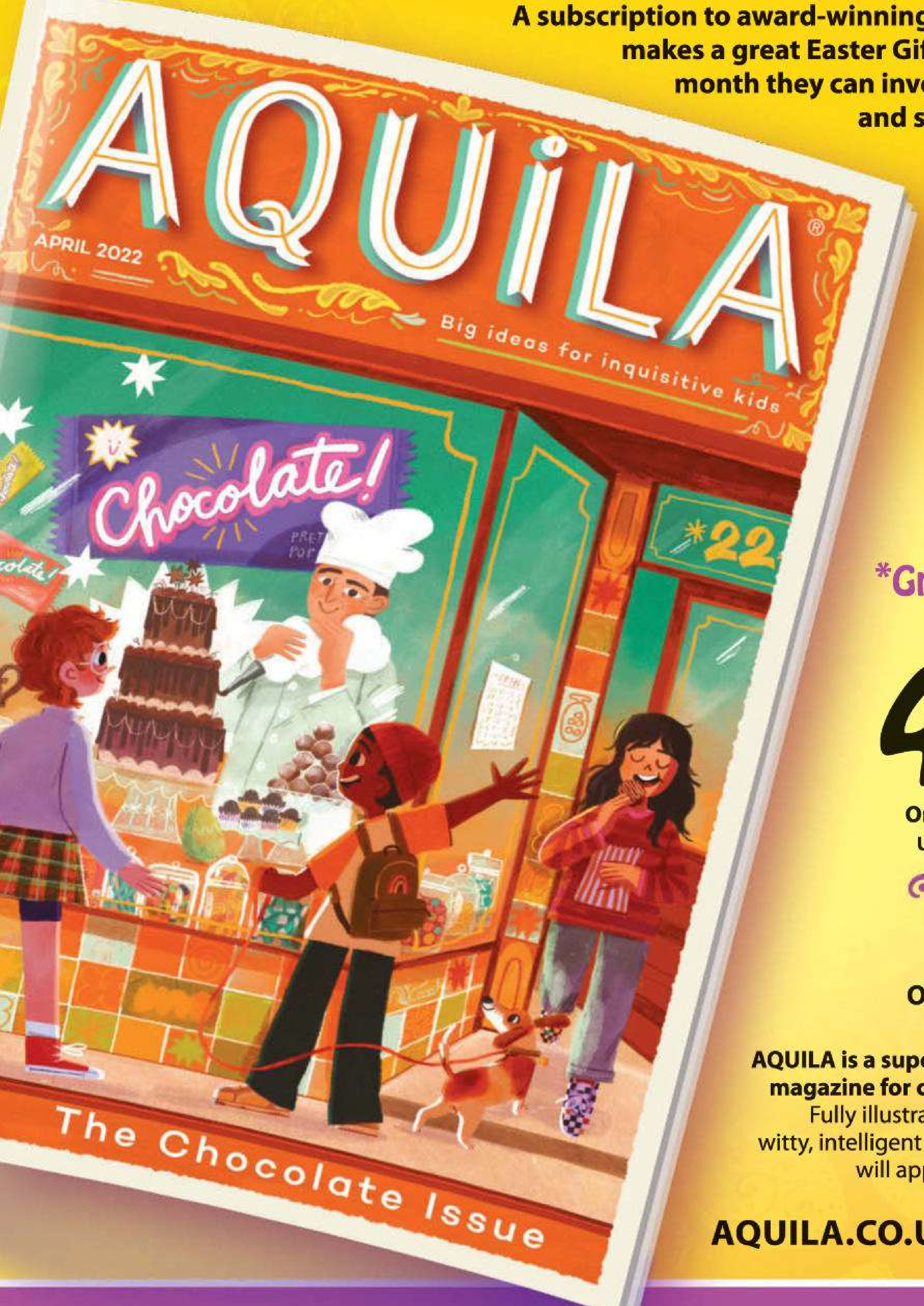

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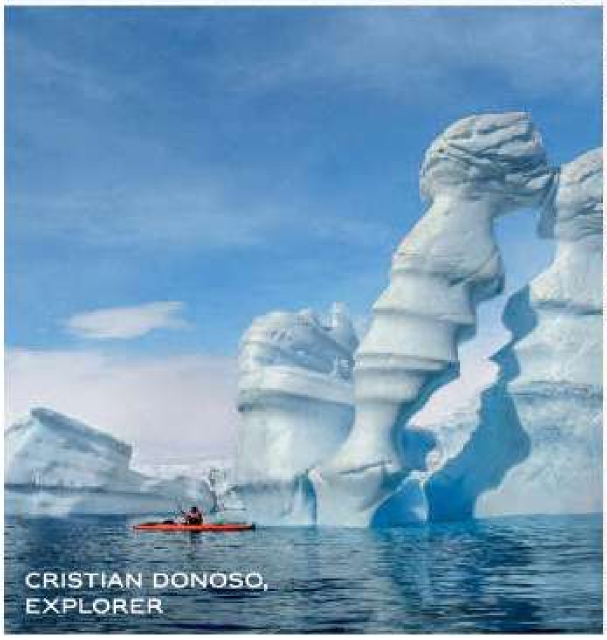
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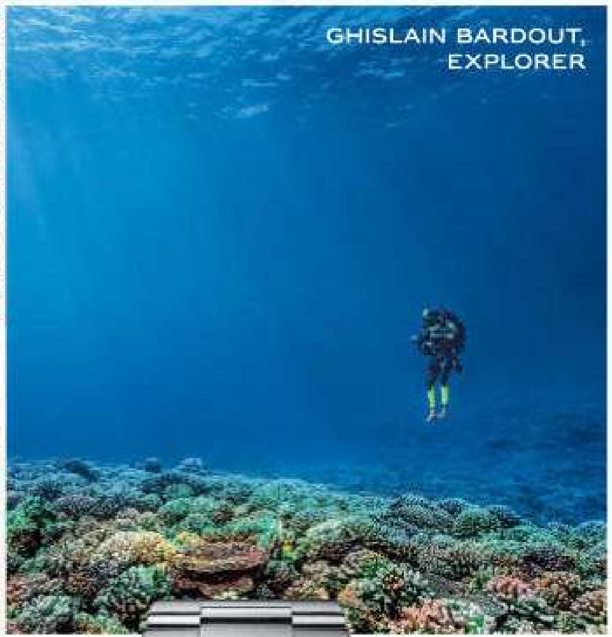
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